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WASTE WATER LAGOON CRITERIA FOR MARITIME CLIMATES

Frederick J. Burgess, et al

Oregon State University
Corvallis, Oregon

1 June 1961

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Progress Report

WASTE WATER LAGOON CRITERIA FOR MARITIME CLIMATES

U. S. Public Health Service
National Institutes of Health
Research Grant RG 6784

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OREGON STATE UNIVERSITY

Engineering Experiment Station Dept. of Civil Engineering

June 1, 1961

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FOR MARITIME CLIMATES

December 1, 1959 to June 1, 1961

U. S. Public Health Service
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Research Grant RG 6784

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SUMMARY

Waste water oxidation lagoon studies are being conducted at Oregon State University to establish criteria for their use in the maritime climates of the Pacific Northwest. The study was initiated with the assistance of the State Sanitary Authority, the League of Oregon Cities, City of Corvallis, and several consulting engineers who recognize that oxidation lagoons promise an economic solution to the waste disposal problem of many small municipalities and industries that cannot afford more elaborate treatment methods.

An experimental facility was constructed consisting of two cells, each one acre in surface area and three feet deep on which studies are being conducted.

Knowledge of loading data as related to effluent quality and other basic parameters should make it possible to define the engineering criteria for application of lagoons to maritime regions. Emphasis is being placed on determination of basic factors influencing lagoon use under various conditions. These include surface reaeration mechanics, sludge accumulation and respiration, bacteriological quality, and disinfection requirements, together with other problems as defined in this report.

Progress made to date indicates that waste water lagoons may be successfully operated in the maritime areas of the Pacific Northwest during the periods of low solar energy without objectional odors or characteristics.

Progress Report
WASTE WATER LAGOON CRITERIA
FOR MARITIME CLIMATES

INTRODUCTION

This progress report has been prepared for (1) engineers and scientists of organizations considering this project for research grant support, (2) engineers for cities and industries having an interest in oxidation lagoons as a practical method of waste disposal, and (3) personnel participating in this and related research. Preliminary results have been summarized according to categories in the body of this report. No specific conclusions have been attempted, however, since the investigators do not feel sufficient data are yet available. Observational data have been included in the appendix for readers desiring more detail.

General Objective

The long-term goal of this project is to gain a better understanding of the biological, chemical, and physical mechanisms involved in the stabilization of organic wastes in oxidation lagoons. Since the practical necessity of applying lagoons to waste treatment needs in maritime climates is most pressing, emphasis during the initial phases of this project has been on loading criteria and related problems. A rigorous experimental approach has been taken, however, to many of the more fundamental problems that will be the bases of future investigations. It is firmly believed that a greater understanding of these more basic relationships will ultimately lead to the solution of waste treatment problems.

Method of Procedure

So that the results of this investigation will fulfill the twofold purpose of providing data useful for immediate application and yet help resolve some of the more basic problems, the research has been divided into two experimental approaches. The two-cell experimental lagoon, which is described in more detail later in this report, serves as the basic facility for testing. Related work in the laboratory and results of lagoon operation at other maritime locations, however, are also used to substantiate findings. Basic data on loading, influent and effluent quality efficiency, and weather are collected routinely, and serve as the nucleus of the project. Separate studies on reaeration, disinfection, oxygen production, and others as enumerated in this report are coordinated with the basic program and serve as

areas of study for graduate students. While the problems of coordinating efforts are at timesdifficult, this approach has served to gather needed information and provide valuable training for sanitary engineering students.

General guidance is given to the project by a committee consisting of C.M. Everts, State sanitary engineer; G.W. Holcomb, head of the Department of Civil Engineering; John Porter, city manager of Corvallis, and Lloyd Clark, consulting engineer. The aid of these gentlemen has been invaluable in maintaining program objectivity.

Contributors

The initial project was undertaken in 1958 at the suggestion of representatives of the Oregon State Sanitary Authority, municipalities, and consulting engineers. Construction of the test facilities was accomplished under a grant of $5875 provided by the Oregon State Sanitary Authority. A single cell lagoon was completed in the fall of that year and studies during the winter of 1958-59 were conducted by Mr. Gerald Whitney, graduate student, while being supported on a U.S. Public Health Service Traineeship. Studies during the summer of 1959 were financed by the Engineering Experiment Station and conducted by Mr. Thomas L. Miksch. Support for three years of study was received from the U.S. Public Health Service, National Institutes of Health, on December 1, 1959. The City of Corvallis, Oregon, has contributed considerable material aid in the form of a lagoon site, labor, and services throughout the project. Without their generous cooperation the project would not be possible.

Significance of This Research

The use of oxidation lagoons as an economic solution to the waste needs of cities and industries in the maritime climates of the Pacific Northwest depends upon the establishment of loading criteria, operational procedures, and the solution of related problems. While considerable research has been done at other locations, many of the problems are regional in character since they are affected by the climate and characteristics of waste quantity and quality. Since annual precipitation exceeds evaporation in the maritime areas, an effluent outfall results. It is felt that studies on bacteriological quality, disinfection requirements, and interpretation of effluent quality will aid in establishing lagoon feasibility. Because of low light intensities during rainy winter periods, accompanied by low

temperature but open water conditions, the studies on sludge accumulation, oxygen production and reaeration are also important.

Many highly colored domestic and industrial wastes may possibly be treated by the lagoon method. Because of the large light extinction coefficient of such colored waste waters, photosynthetic production of oxygen by algae is severely limited even during the summer months. Reoxygenation of lagoons under these condtions must be largely from surface sources. Hence, studies of reaeration mechanics and development of experimental methods for determining reaeration constants are important. The Pacific Northwest maritime area is characterized by winters of high rainfall and low light intensities. Summer periods, however, have prolonged dry periods, and many streams available for effluent dilution have very low minimum flow. Studies on evaporation and water balance in the lagoon and interpretation of the effect of effluent quality upon the receiving stream during these periods is of major importance.

DESCRIPTION OF EXPERIMENTAL FACILITIES

The experimental lagoon is located 600 feet north of the Corvallis, Oregon, sewage treatment plant. The unit consists of two cells, each 1.07 acres in surface area with an adjustable liquid depth. All research to date, however, has been conducted at a 3-foot depth. Dikes enclosing the unit are 8 feet across the top and have a side slope of 2 horizontal to 1 vertical. Raw sewage is discharged into the center of each cell through a 6-inch fiber pipeline. Outlets from each cell are at the south dike and discharge into a drainage ditch. Control facilities permit loading the two cells at different rates under the same environmental conditions. Permanent stations (see Fig. 1) for studying sludge accumulations, bacteriological conditions, and other tests are referenced by poles and signs to permit comparative studies over a period of time. The cells are enclosed by a 5-strand barbed wire fence and suitable signs (see Fig. 2) indicating the nature of the study and warning the public as to the lagoon contents are displayed on the fence. The lagoon effluent enters an outfall sewer within the fenced area that discharges to the Willamette River. A parking lot, walkways, analysis shelter, docks, and two boats serve as support facilities.

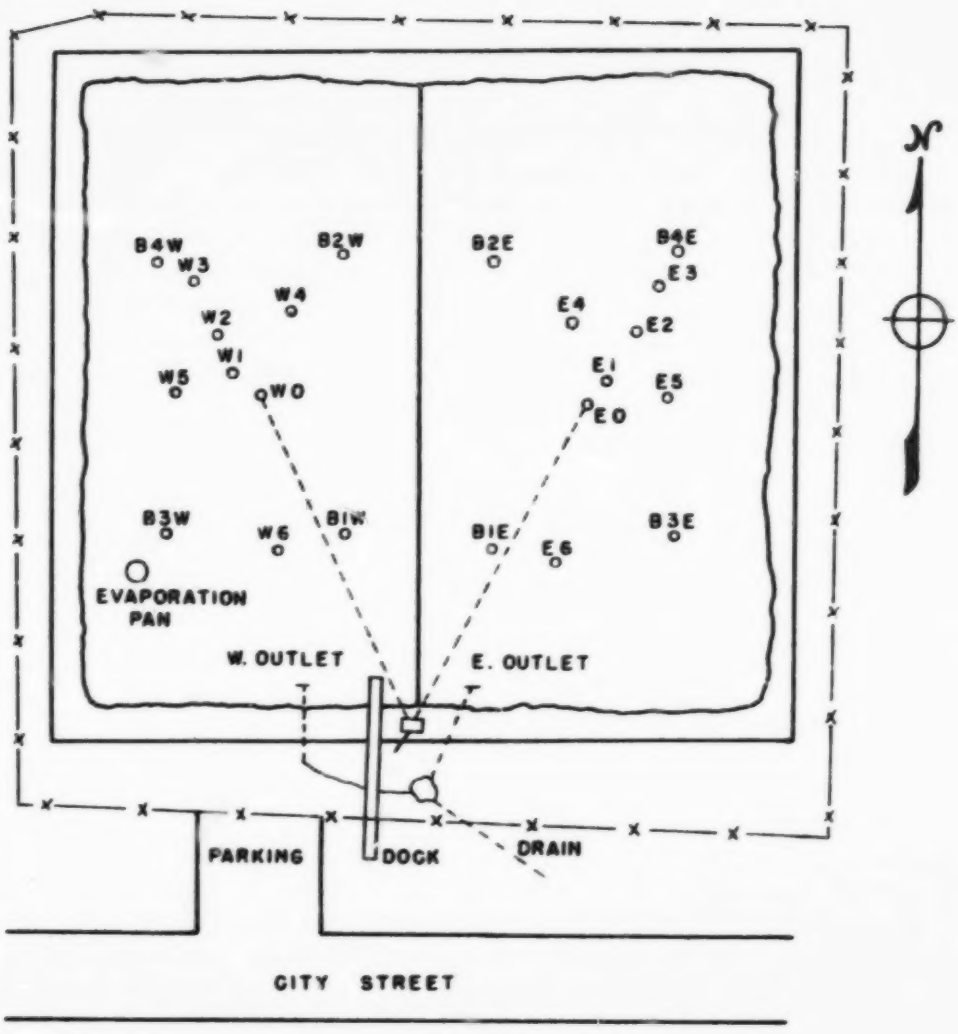

Figure 1. Experimental Lagoon Plan

Figure 2. Experimental Lagoon

Control Equipment

Sewage is pumped to the lagoon site by a 350 gpm sewage pump. Control of total quantity is accomplished by adjusting pumping time with a time clock system. The pumping time is set to coincide with the sample compositing mechanism in the sewage treatment plant in order that representative samples can be obtained. The pump intake is on the return elbow of the sewage plant comminuter; hence, a comminuted raw sewage is obtained. The discharge piping to the lagoon consists of two 4-inch steel pipelines that terminate in the intake box of a Parshall flume with a 3-inch throat. A 7-day liquid level recorder provides continuous monitoring of the system to insure correct operation. Division of flow between the west and east cells is accomplished by a broad-crested weir with a movable center divider so as to split the flow as required.

Climatological Measurement

Since lagoon performance is closely related to climatological conditions, rather complete weather data are obtained. Data on temperature and precipitation are obtained from Oregon State University Farm Crops Department. Solar energy measurements are made with an Eppley pyrheliometer equipped for continuous recording located 3 miles southeast of the experimental lagoon. Results of the solar energy measurement are recorded in terms of gram-calories per square centimeter.*

Net precipitation-evaporation measurements are made in an evaporation pan 4 feet in diameter and 3.5 feet deep, sunk in the lagoon and equipped with a Stevens hook gage. The pan is silver in color. No significant temperature differences have been found to exist between it and the lagoon. A summary of climatological data in terms of monthly averages is given in Table 1.

Laboratory

Major testing is accomplished in the Sanitary Engineering laboratory of the Department of Civil Engineering. Facilities of the Department of Bacteriology and the City of Corvallis are used as needed. A shelter is provided at the lagoon site and serves as a laboratory for analyses that need to be made immediately upon collection.

*A gram calorie per square centimeter per day is equivalent to 1 langley/day.

Table 1. Weather Data Summary

	Air temperature, °F**			Precip**	Solar energy*	Evap**
	Max	Min	Mean	in.	gm cal/cm^2/day	in.
January	45.3	32.5	39.0	6.42	109	-
February	50.5	35.1	42.8	5.10	132	-
March	55.3	37.0	46.2	4.06	164	-
April	62.3	40.5	51.4	2.10	395	2.55
May	68.8	44.9	56.9	1.85	454	4.05
June	73.4	49.3	61.4	1.29	685	4.64
July	81.3	51.9	66.7	0.32	697	4.35
August	80.9	51.4	66.2	0.38	524	6.00
September	76.8	48.8	62.8	1.30	406	3.94
October	64.7	43.4	54.3	3.53	234	2.05
November	53.1	37.5	45.4	5.44	128	-
December	48.1	35.7	41.7	6.15	91	-

* Data available.

**Approx 25-year average.

Diurnal variations in solar radiation affect lagoon performance. A comparison of variation throughout the day expressed as an average is shown Fig. 3 for summer and winter months.

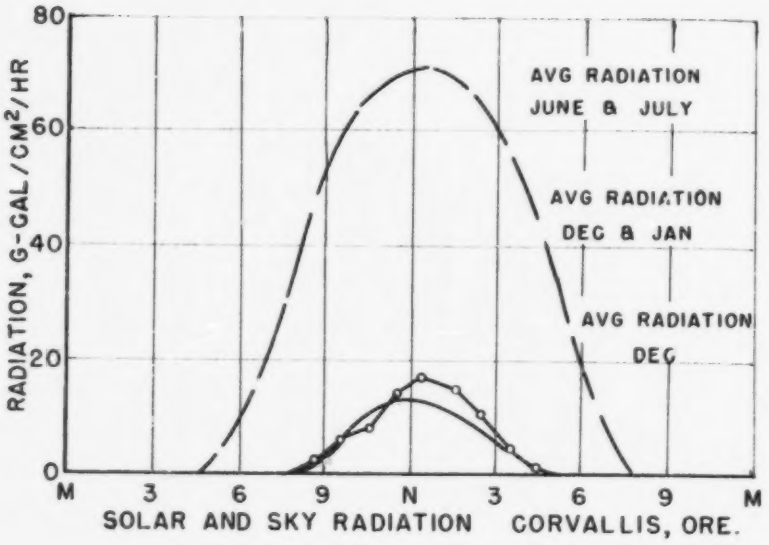

Figure 3. Diurnal Variation in Solar Radiation

PRELIMINARY RESULTS

Loading Data

The primary measures of loading in this study were flow, 5-day biochemical oxygen demand (BOD), and suspended solids (SS). Other tests have been included but not on a routine basis.

Since 5-day BOD is a most widely accepted parameter for sewage strength, this measure was used as the principal loading criterion. In order to establish acceptable loading values, 50 and 100 pounds of 5-day BOD per acre per day were selected as loading rates for the east and west cells of the experimental lagoon as the initial target values for the first year of study. Variations in strength caused some departures from these values.

Figure 4 gives average monthly loadings in terms of pounds of 5-day BOD per acre per day. Difficulty in adjusting flow rates to sewage strength prevented exact loadings. This was not considered a serious problem, however, because of the compositing effect of the lagoon.

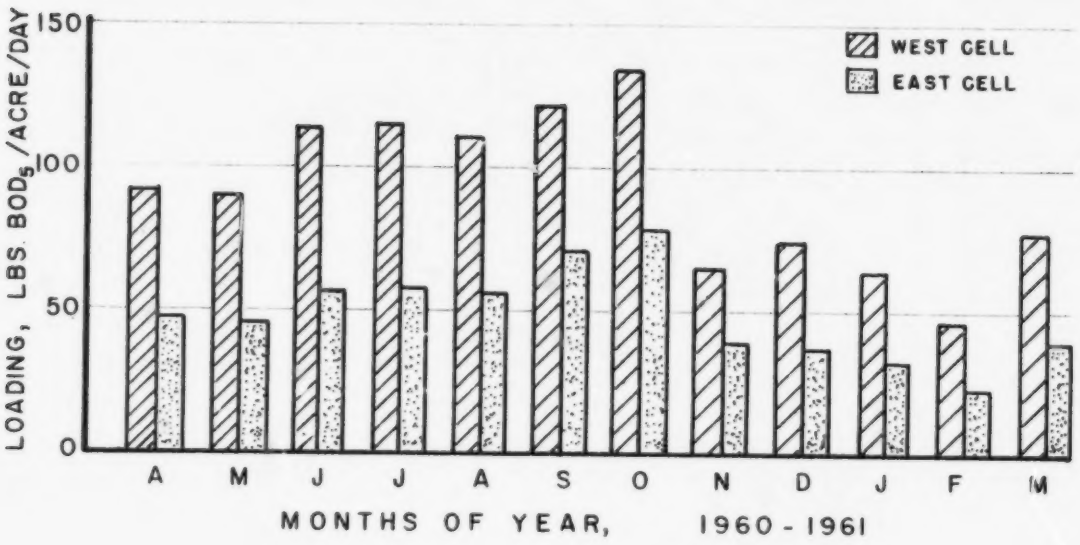

Figure 4. Average Loading Rates - BOD

Failure in the west cell occurred first in September and again in October and November. This failure was accompanied with low to zero dissolved oxygen, floating sludge, very objectionable odors, low pH, and poor removal efficiency. Periods of recovery were permitted during the above months, hence the values shown represent averages during days of loading rather than true monthly average.

The principal cause of this failure was large loadings of highly colored beet cannery wastes. The increased light extinction reduced algal activity to below the critical level, and dissolved oxygen production did not keep pace with requirements for aerobic decomposition, hence septic conditions were established.

The east cell, loaded at one-half the rate of the west cell, continued to function satisfactorily without nuisance during this same critical period.

In February 1961, flood waters inundated both cells resulting in a nearly complete change of wastes in the two cells. Since February, loading has been at higher rates than were originally planned so that conditions similar to those that existed before the flood could again be established.

Suspended solids (SS) determinations were made and monthly averages in pounds of SS per acre per day are presented in Fig. 5. Studies of bottom sludge accumulation as related to suspended solids are being conducted and are covered in a separate section of this report.

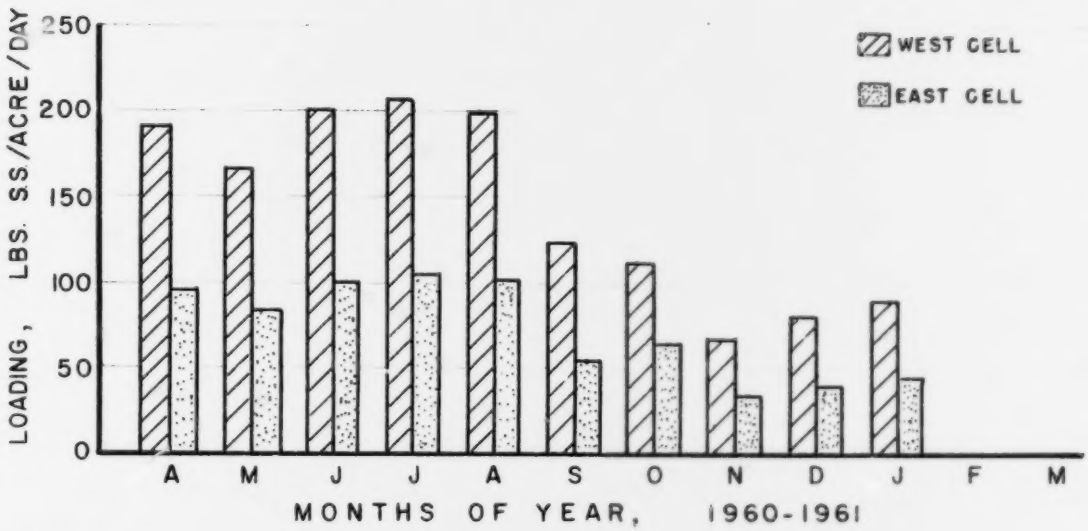

Figure 5. Average Suspended Solids Loading

Since the expression of loading criteria for this study is 5-day BOD per acre per day, flows and detention times are a function of BOD of the influent. For this reason, detention times varied as changes in BOD were encountered. Detention times for both cells were calculated and are presented in Table 2. Attention is called to the values listed for the west cell during the months of September, October, and November. For reasons discussed previously, these listed values are not true monthly averages.

Table 2. Volumetric Loading

	West cell		East cell	
	Detention days	Days loaded	Detention days	Days loaded
April	18.6	- 26	37.2	26
May	18.6	31	37.2	31
June	18.6	30	37.2	30
July	20.2	31	40.5	31
August	21.2	31	42.0	31
September	130.0*	6	43.9	30
October	64.0*	17	43.9	31
November	103.0*	7	50.0	30
December	23.2	31	46.6	31
January	19.8	31	39.6	31
February	10.9*	24	21.8*	24

*Loading not continuous

Quality of Effluent

Tests for an indication of the quality of effluent from the two cells of the lagoon used in this study included dissolved oxygen (DO), pH, BOD, transmittance of light, coliform density, chlorine demand and others.

The results of dissolved oxygen determinations are presented as monthly averages in Figure 6. The concentration varied from supersaturation during early spring and summer to zero at the point of failure. These reported averages are from measurements taken at approximately 2:00 PM daily. Since DO concentration is maximum in the midafternoon, during the midafternoon the slope of the diurnal fluctuation curve (see Fig. 13) approaches zero. Two PM was chosen as the most probable time in a winter-summer operation for this maximum condition to occur.

While results so obtained are not of great accuracy, they are indicative of DO levels and minimize the possibility of sampling at a time when the rate of change of DO is great. Included in the dissolved oxygen averages of the west cell for the months of September, October,

and November are DO taken during the period of recovery. This would account for the high concentrations immediately following times when failure has occurred.

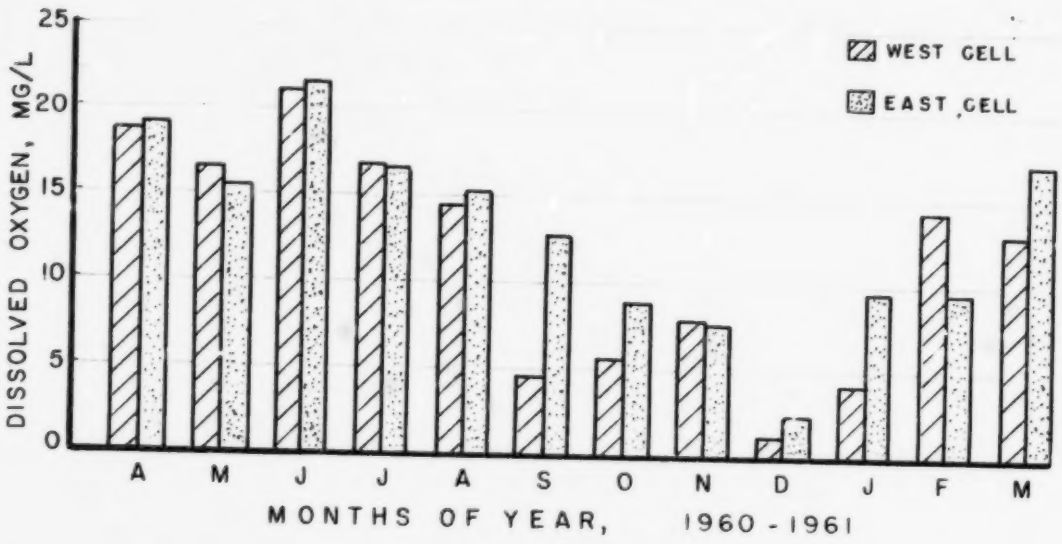

Figure 6. Dissolved Oxygen Averages

A sampling depth of 6 inches below the surface and at the point of outlet to the receiving stream in each cell was used for routine measurements. The unmodified Winkler method was employed in determining DO values, and it was recognized that interfering elements and compounds were probably present in these samples being tested.

Dissolved oxygen values that have been determined as recorded in the appendix and summarized in Fig. 6, were not intended to be absolute values but merely one determination in a daily and hourly changing situation which indicated general condition. These data represent qualitative rather than quantitative determinations.

pH was determined for the effluent discharge from the two cells of the lagoon. The monthly median of pH and the pH range for each cell is presented in Table 3.

Table 3. pH Data Summary

	West cell		East cell	
	Median	Range	Median	Range
April	8.8	7.0-10.4	9.0	7.3-10.8
May	9.2	8.5-10.6	9.2	8.3-10.6
June	9.5	8.0-11.0	9.9	8.5-10.8
July	9.1	8.3-10.4	9.3	8.2-10.7
August	9.3	7.0-10.0	9.7	8.3-10.7
September	7.3	7.0- 9.5	7.2	7.0- 9.5
October	7.3	6.6- 9.4	8.7	7.1-10.2
November	7.1	7.1- 8.6	7.5	7.2- 8.5
December	6.8	6.5- 7.1	7.0	6.9- 7.4
January	7.1	6.2- 7.4	7.2	6.2- 8.4
February	7.3	6.9- 8.6	7.3	7.0- 8.1
March	7.6	7.6- 9.1	8.3	8.0- 9.2

The quality of effluent in terms of percent of BOD removed is presented in the form of monthly averages in Fig. 7. Efficiencies were calculated from 5-day, 20 degree BOD data from the raw influent and from the effluents as they were discharged to the receiving stream with no additional treatment. Efficiencies calculated on this basis indicated a high degree of removal well above 80 percent during the periods of aerobic operation. An inspection of BOD data just prior to the failure and recovery period of the west cell in August, and calculation of efficiencies, will show values as low as 23 percent.

Since the conventional BOD tests measure total oxygen respiration in the sample bottle during incubation, the values may have little bearing on the pollutional nature of lagoon effluent. Much of the material is in the form of living cells that would not affect the receiving stream in the manner they affect BOD measurement. The rather basic question of interpreting results remains for future study.

The nature of the materials causing BOD becomes critical, particularly in those cases where disinfection is required. Determination of BOD to include the algal cells was performed on seeded samples, both filtered and unfiltered. An inspection of the data in the appendix shows a comparison of the untreated filtered and unfiltered effluents.

Heat killed unfiltered samples probably represent more nearly the true BOD load placed on the receiving stream when disinfection of the effluent is practiced. It is noted in most cases that the BOD for the heat killed unfiltered samples is higher than that of the untreated samples. In many instances the total load of BOD leaving an oxidation lagoon may be higher than that in the incoming raw sewage if disinfection is done on the effluent stream.

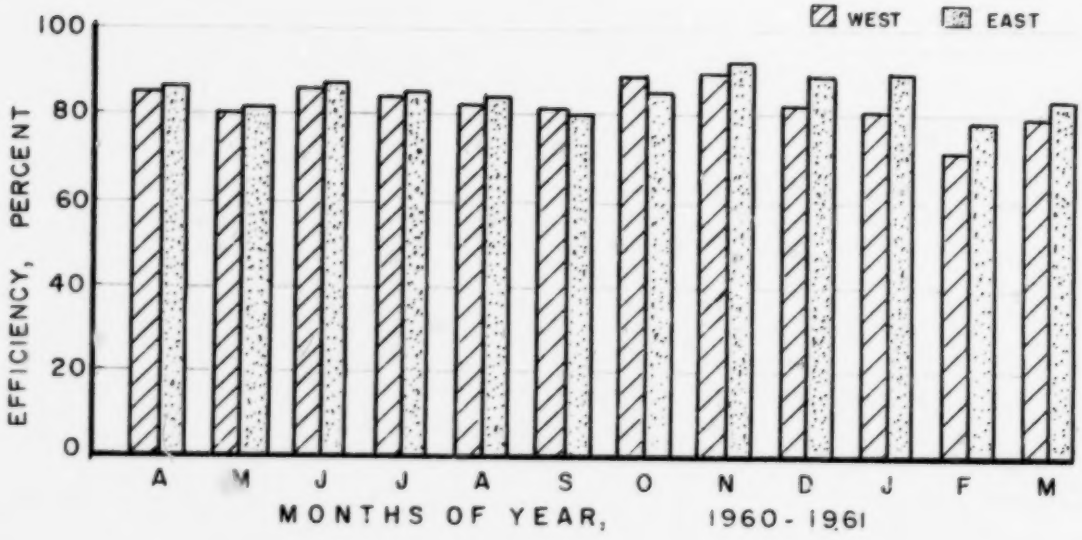

Figure 7. Average Efficiencies of BOD Removal

Transmittancy determinations were made on raw samples of the influent and effluent for comparison purposes. These samples were placed in a centrifuge and run for 15 minutes at 3000 rpm. The centrifuge supernatant and the residue were then separated and transmittance determinations were made on the supernatant on a Beckman spectrophotometer at a wave length of 650 microns. Results of these determinations are presented in the appendix.

Values determined for transmittancy ranged from approximately 70 percent to 95 percent for the effluent from the two cells and the influent. No particular correlation is evident at this time of the study. The data are collected routinely, however, because they are felt to have bearing on critical light levels and oxygen production.

During the period from April to September, the color of both cells was dark green, as associated with high algal activity. No offensive odors were detectable. This appearance was associated with an aerobic condition. In early September, the west cell began changing from a green to a gray color. Algal counts dropped proportionately, and around the edges of the west cell a red ring of tubifex was observed. The change in aquatic life was punctuated by very objectionable odors and floating sludge, associated with an anaerobic condition. The loading of the west cell was discontinued to permit reestablishment of satisfactory aerobic conditions.

A recovery period of about 5 days was permitted, during which objectionable odors changed, algal activity increased, and the tubifex disappeared. Loading to the west cell was started before a complete recovery, however, because the failure cycle was experienced twice more in the following months. Through the winter months, algal activity in the east cell was low and the color turned gray, but at no time was there any floating sludge or tubifex observed or objectionable odors detected.

The east cell, loaded at one-half the rate of the west cell, has operated satisfactorily throughout the initial test period. It is felt that the critical loading circumstances were bracketed in the initial test, and future work to more closely define the critical level is being planned.

Foam caused by detergents has been observed at the outlets of the cells of the lagoon. Figure 8 shows this condition on a typical day. The free fall of the outlet causes sufficient turbulence to cause foam. Detergent survival through the process is a subject of current study.

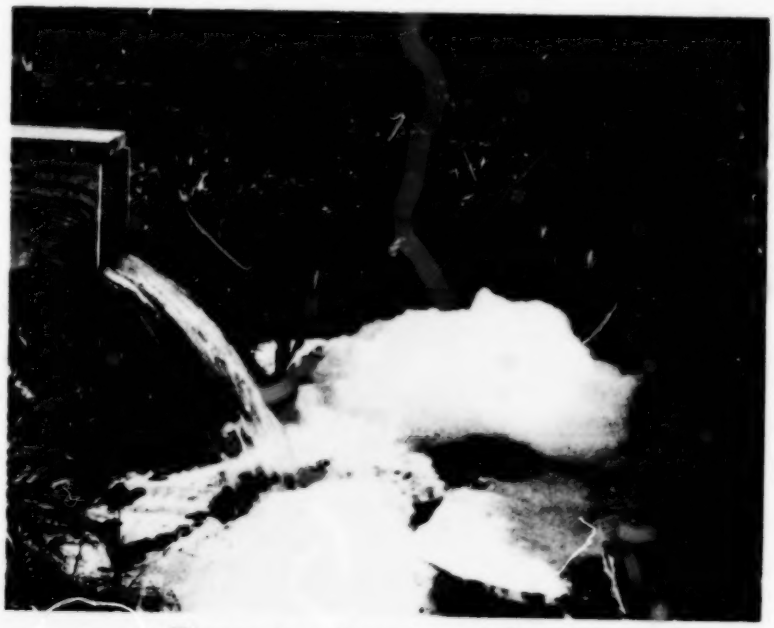

Figure 8. Foaming at Outlets

Bacteriological Studies

Bacteriological quality of the lagoon effluent is of particular importance in a maritime region. Since annual precipitation exceeds annual evaporation, a lagoon effluent must be disposed of by dilution into an existing water course, used for irrigation, or handled in some other satisfactory manner. In all cases the bacteriological quality must be considered. This quality will be quite variable, and is not only affected by bacterial specie, lagoon environment, and waste water quality, but also by the location of the inlet to the outlet, wind direction, lagoon short circuiting, and rate of hydraulic loading or detention time. As may be expected, the bacteriological quality of the lagoon effluent varies from day to day and within the time of any one day. More detailed investigations of these variations are the subject of current study.

Because of the limited research staff, bacteriological studies were limited to samples collected on selected days near 10:00 AM. These were analyzed for coliform density by the millipore filter technique. A 47 mm type H. A. filter, grid marked with 0.45 micron pore openings, was utilized, together with M-Endo Broth M. F. 0749-01 as produced by Difco laboratories. Manipulative technique employed

was that listed Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 11th ed., American Public Health Association, et al, and as suggested by Mr. H.F. Clark, microbiologist with the U.S. Public Health Service at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

Results of bacteriological studies to date are given in Table 4 in terms of hundreds of bacteria per milliliter of effluent. To convert these figures to the standard MPN units of coliform organisms per 100 mls, multiply the given value by 10,000.

Table 4. Bacteriological Data

Date	Day of wk	Coliform bacteria per ml/100* Raw	West	East	Date	Day of wk	Coliform bacteria per ml/100 Raw	West	East
1960									
7-15	F	40	3.8	3.15	9-12	M	440	6.5	80
8- 3	W	70	10.2	4.2	9-14	W	210	-	9
8- 6	S	70	60	20.4	9-16	F	360	2.0	17.5
8- 8	M	350	29	7	9-21	W	110	1.7	18
8-10	W	700	24.6	26	10-28	F	160	12.0	1.3
8-12	F	1800	29	23	11-11	F	20	-	0.5
8-15	M	25	11.8	6	12-19	M	50	2.4	0.45
8-17	W	170	36	15	12-30	F	770	14	0.6
8-24	W	280	35	10	1961				
8-29	M	1600	38	79	1- 7	S	30	22	2.4
8-31	W	700	18	6.5	1-14	S	30	2.4	3.2
					1-28	S	25	0.15	0.15
					2-18	S	8.0	0.88	0.83
					3- 4	S	2.0	0.7	0.2
					3-11	S	13.5	0.55	0.2
					3-25	S	1.0	3.0	0.1

*Coliform/ml = reported figure × 100
Coliform/100 ml = reported figure × 10,000

Disinfection Requirements

The percentage reduction of coliform organisms through the oxidation lagoon is rather large. The bacteriological quality of the effluent, however, indicates that based on current standards, disinfection may be required under some circumstances. Merits of disinfection and the problems of after growth are recognized. Since these are the subject of current studies at the Robert A. Taft Sanitary Engineering Center, no attempt has been made to interpret disinfection needs in this report.

Chlorine requirements for disinfection were studied on the basis of the required dosage to obtain a total chlorine residual of 0.5 mg/L after 30 minutes contact time. This was accomplished by dosing samples with various amounts of chlorine so as to bracket the requirement values. The residual in each sample was determined after 5 minutes contact time. Table 5 is a listing of data so determined.

Table 5. Disinfection Requirements

	Cl_2 requirement mg/L to 0.5 mg/L residual		
Date	Raw influent	West effluent	East effluent
1960			
8- 1	6.0	6.0	6.0
8- 8	5.0	6.0	9.0
8-15	10.0	6.0	6.0
8-19	4.0	5.0	8.0
8-22	7.5	7.0	7.5
8-29	-	13.5	13.5
8-31	13.0	10.5	16.0
9- 5	6.0	6.0	12.0
9-12	-	6.0	8.4
9-19	9.0	3.0	9.0
10-28	2.0	3.0	3.0
12-19	2.0	4.0	2.0
12-24	5.0	2.8	2.0
1961			
1- 7	3.0	2.0	2.0
1-14	3.0	2.0	2.0
2-14	7.0	2.5	2.0
3- 4	-	3.0	2.0
3-11	2.0	1.5	1.5
3-18	1.0	1.0	2.0

No attempt has been made to correlate the chlorine requirement with various related parameters. It should be noted that the chlorine demand of the effluent is at times greater than that for raw sewage. Your attention is directed to the section entitled, "Quality of Effluent," for consideration of the major problem involved in effluent chlorination. Algae killed coincident to chlorination contribute a significant source of dead and readily decomposable organic matter to the effluent stream. In many cases, the quality of effluent from a BOD standpoint may be equivalent to raw sewage. This factor indicates that either closely controlled chlorination of the influent, so as not to affect lagoon operation or removal of algae prior to effluent chlorination, is required if disinfection is necessary.

Reaeration Mechanics

Reaeration at the lagoon surface by transfer of oxygen across the liquid-air interface is of considerable importance in oxidation lagoons. While the principal source of dissolved oxygen is from photosynthetic production by algae, this mechanism depends upon maintenance of an adequate plankton population. Several factors may severely limit or destroy phytoplankton growth. These include toxic materials, overloading, large blooms of rotifers or crustacea, exhaustion of nutrients, and other environmental changes unsuited to good algae production. A major source of trouble has been encountered in the experimental oxidation lagoon during periods of highly colored beet canning wastes, which severely reduce the light extinction coefficient and, hence, algal activity. During any period of low oxygen production by algae, reaeration from the surface is the principal source of oxygen.

The basic approach used to study surface reaeration has been to apply the gas transfer equation

$$dD/dt = -K_2 D$$

where D is oxygen deficit at the observed temperature, or the difference between the saturation value for dissolved oxygen at that temperature and the actual concentration of dissolved oxygen present. dD/dt is the rate of change in deficit with time. Since dD is proportional to change in dissolved oxygen, d(DO), the equation may be written in terms of weight of oxygen, dw, as uptake in pounds of oxygen per surface acre per 24-hour period for the 3-foot lagoon.

$$dw = \frac{d(DO)(43,560)(62.4)(3)}{1,000,000}$$

$$dw_{lb} = d(DO) \times 8.15$$

The equation then becomes

$$\frac{dw}{dt} = \frac{d(DO)\ 8.15}{dt} = K_2 D$$

if dt is in hours, K_2 has the units of reciprocal hours and the total uptake in terms of pounds of dissolved oxygen transferred per surface acre per day at steady state conditions may be calculated by

$$lb/day = K_2 D \times 24$$

Since oxygen transfer is affected primarily by mixing within the lagoon, surface winds, and condition of the surface, the initial research approach has been to describe total mass transfer. Several light cells consisting of a clear plastic shell and a surface cover were constructed for placement in the lagoon. Figure 9 is an illustrative sketch of the experimental apparatus.

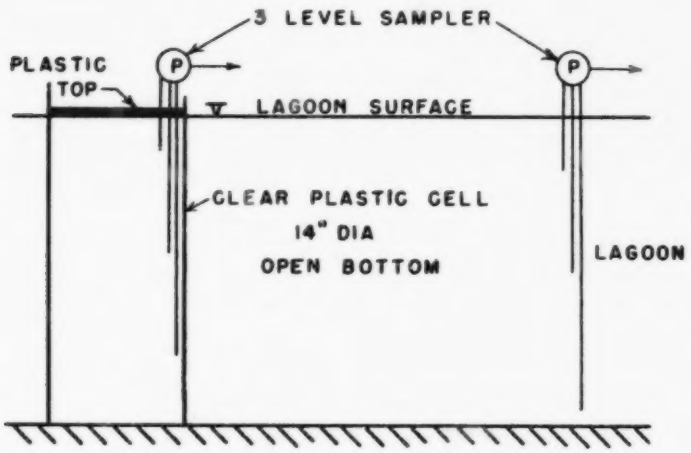

Figure 9. Reaeration Study Apparatus

The cell is placed in the lagoon at time zero, selected when the oxygen content in the lagoon is below saturation. Samples are taken at the surface, mid-depth, and near the bottom by a sampling pump to determine the true average dissolved oxygen in each system. At dt time later (normally 4 to 6 hours), samples are again taken to determine the oxygen present. Two curves are thus developed as illustrated in Figure 10.

Separation of the two curves is an indirect measurement of oxygen supplied from surface sources. While this method is somewhat

cumbersome and subject to experimental errors, it has proved feasible. Additional work is being done on improvement of method and elimination of sources of error. Typical data obtained by this approach and their analysis are given in Table 6.

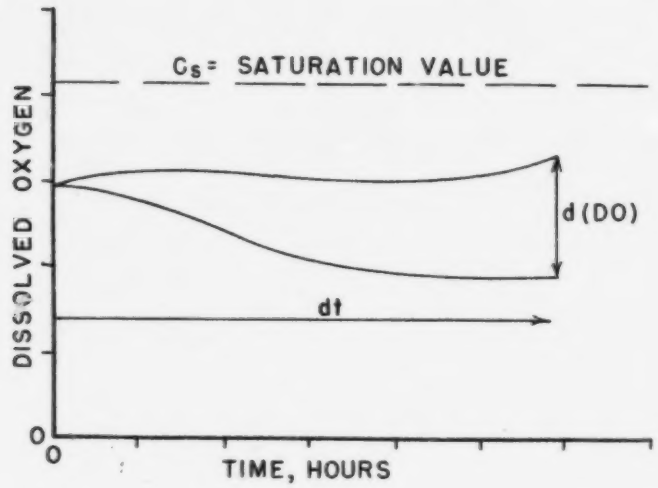

Figure 10. Oxygenation Curves - Lagoon vs Test Cell

Table 6. Typical Reaeration Data

Time	Lagoon DO mg/L	Clear cell DO mg/L	Temp °C	Deficit "D" mg/L	$\frac{d(DO)}{dt}$	$\frac{dw}{dt}$	Kr
0	2.65	2.63	3	10.8			
					0.184	1.48	0.143
6	3.05	1.95	5	9.8			
					0.240	1.94	0.206
12	3.80	1.25	5	9.0			

Values of Kr determined by this method have a range of 0.038 to 2.3, with a median value of 0.206. For convenience, a multi-correlation chart is shown in Fig. 11, giving the pounds of oxygen that may be transferred per surface acre per day at steady state conditions of constant deficit. The value of 0.206 is tentative and subject to review on the basis of future investigation. It may be seen, however, that significant oxygen is obtained from surface sources.

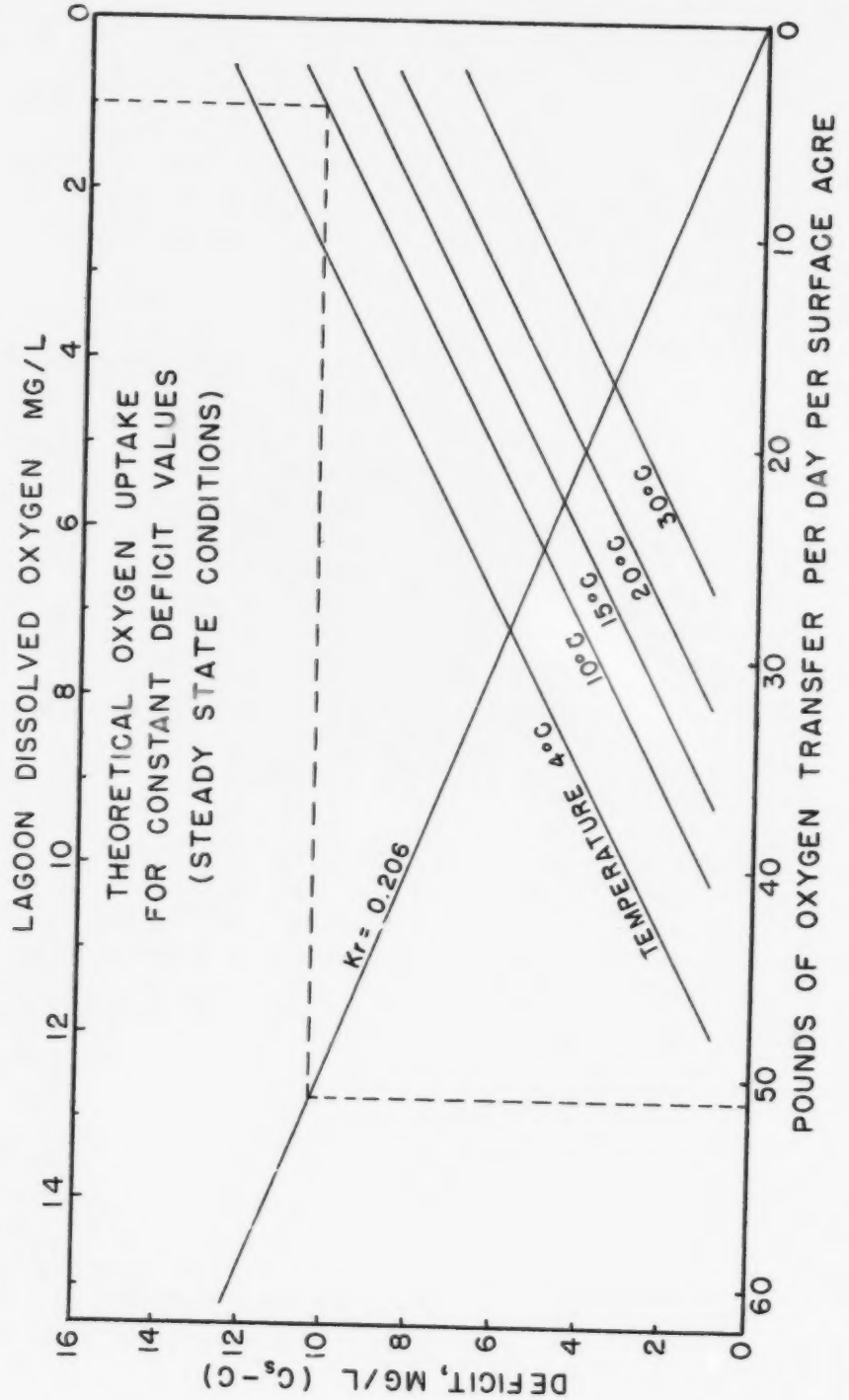

Figure 11. Reaeration Rate - Multicorrelation Graph

Sludge Accumulation

Sludge accumulation and distribution is an important consideration in oxidation lagoon criteria. Since the sludge blanket is in a constant state of change, single samples from one location have little significance. A program of determining change in sludge depth, composition, and distribution has been undertaken in the lagoon study. Core samples are collected in plastic sample tubes 1.25 inches in diameter from permanent sampling stations. These are analyzed for sludge composition and depth. Table 7 is a partial tabulation of the limited data available from these tests. Figure 12, showing typical sludge samples, illustrates the sampling tubes and sludge variations noted. Sample numbers are referenced to stations shown on Fig. 2, and to sample identification; i.e., sample L10, B3W is sample no. L10 at location B3W.

Table 7. Sludge Accumulation Data*

West cell				East cell			
Location	Depth ft	$\frac{lb}{ft^2}$	% vol.	Location	Depth ft	$\frac{lb}{ft^2}$	% vol.
W1	0.61	3.90	32	E1	0.72	3.82	54
W2	0.57	2.89	33	E2	0.55	1.95	41
W3	0.42	1.69	32	E3	0.30	1.08	35
B4W	0.39	1.67	30	B4E	0.33	1.42	37
B2W	0.23	1.07	31	B2E	0.15	1.56	22
W4	0.30	1.38	28	E4	0.25	0.89	35
W5	0.23	1.07	29	E5	0.27	1.31	33
B3W	0.25	1.03	28	B3E	0.22	0.92	32
W6	0.22	0.76	29	E6	0.26	1.88	22
B1W	0.35	1.90	25	B1E	0.26	2.02	22
W0F	0.16	1.70	13	E0F	0.24	3.56	10

*Data from samples taken March 21, 1961.

lb/ft^2 = pounds of sludge per sq ft of bottom

Percent fixed = 100 - percent volatile

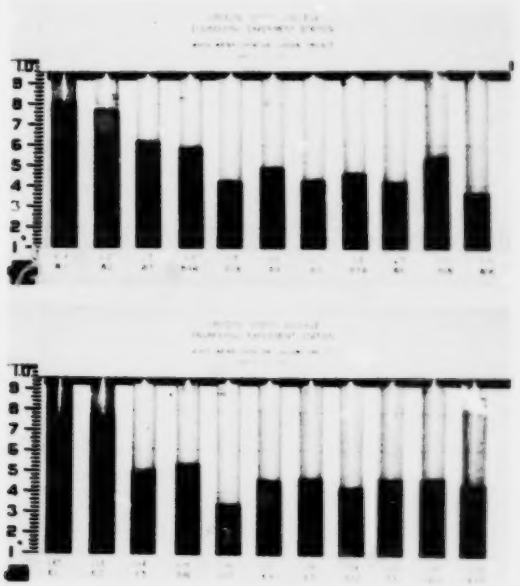

Figure 12. Sludge Samples

Oxygen Production

Oxygen relationships are of importance in the experimental lagoon study because production of oxygen by algae is the principal source of oxygen available for reaeration. While detailed studies of the biological mechanisms have been made by other investigators, certain tests have been conducted in order to determine the effect of the various conditions characteristic of a maritime climate. Oxygen production in the lagoon is affected primarily by solar energy incident to the lagoon. However, algae specie, density of algal cells, temperature, and quality of the wastes in the lagoon also have an effect.

Interpretation of dissolved oxygen content in the lagoon at any time becomes impossible without considering the diurnal variation.

Figure 13 shows the oxygen variation on July 16, 1959, and is typical of a bright, summer day with solar energy in the range of 570 grams calories/cm^2 per day. It is of interest to note that the point of highest concentration varies with the time of year. For this reason, a procedure of measuring the dissolved oxygen at 2:00 PM has been adopted for routine work. Figure 3 gives the variation in

solar energy for a day's period as averaged for the summer and winter months. The magnitude of oxygen variations has been found to be somewhat similar to the curves shown.

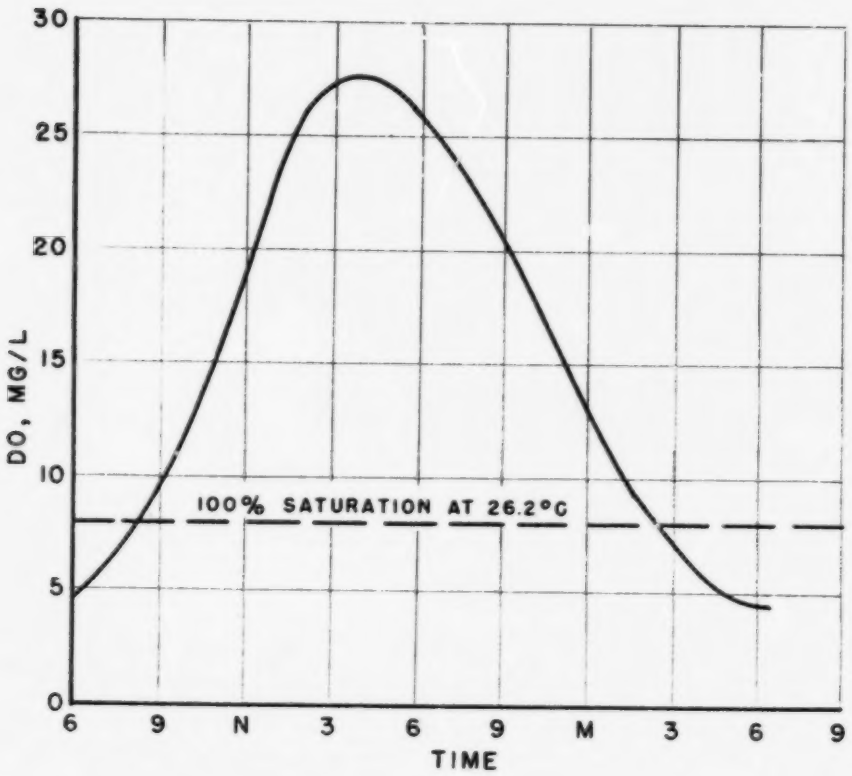

Figure 13. Diurnal Oxygen Variation at Lagoon Surface

Production of oxygen was determined by the standard dark-light bottle test. Figure 14 gives the results of an analysis of variation in oxygen production with depth on January 2, 1959, with a light energy of 177 gram calories/cm^2, temperature 8.7°C, wind 1.50 mph-SW, and precipitation of 0.08 inch. Plankton present on that date in terms of ppm by wet volume were chlomydomonas 1-2 ppm, and scenedesmus amatus 7.2 ppm. It will be noted that 65 percent of the oxygen production occurred in the first 12 inches of depth. Justification of greater depths must therefore be based largely upon sludge storage and aquatic weed control.

Oxygen production in other depth increments and its variation throughout the day is shown by Figure 15. It will again be noted the significant production occurs in the top layer.

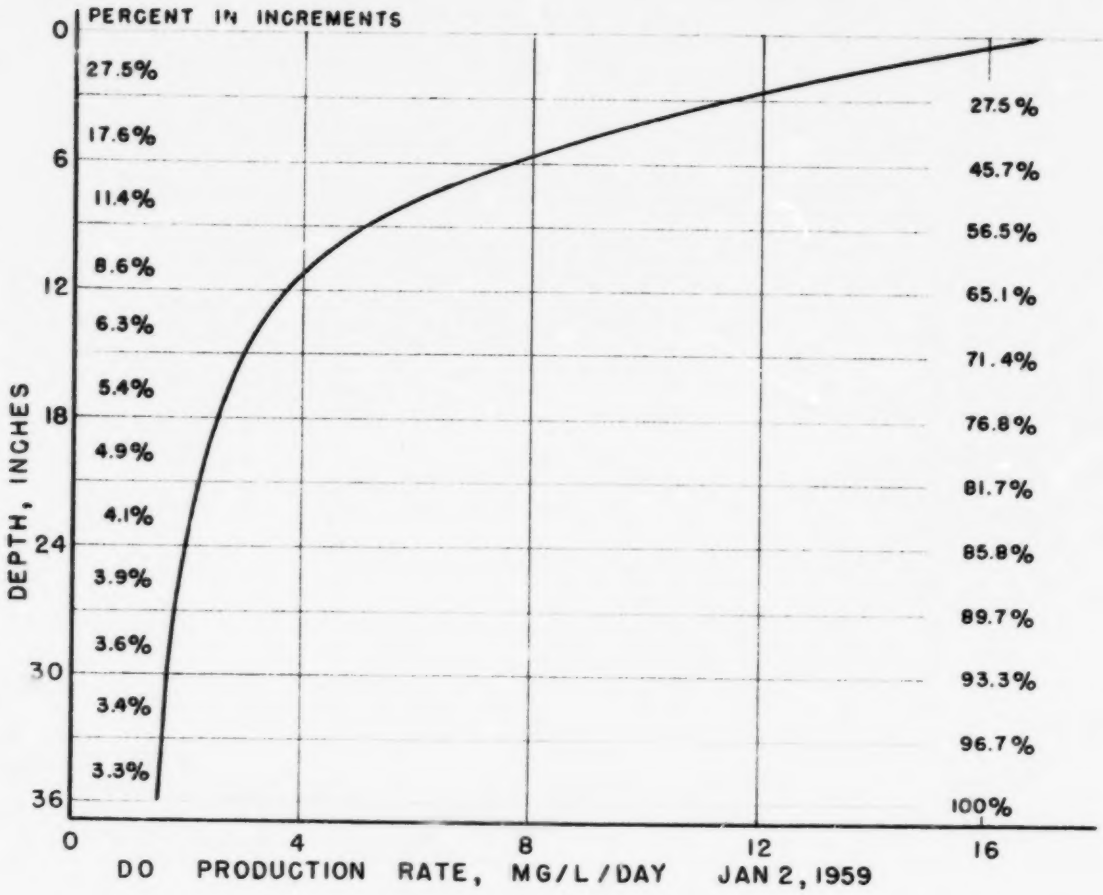

Figure 14. Oxygen Production vs Depth

Studies of light extinction versus waste color are planned to consider the important question of how waste color variations affect oxygen production.

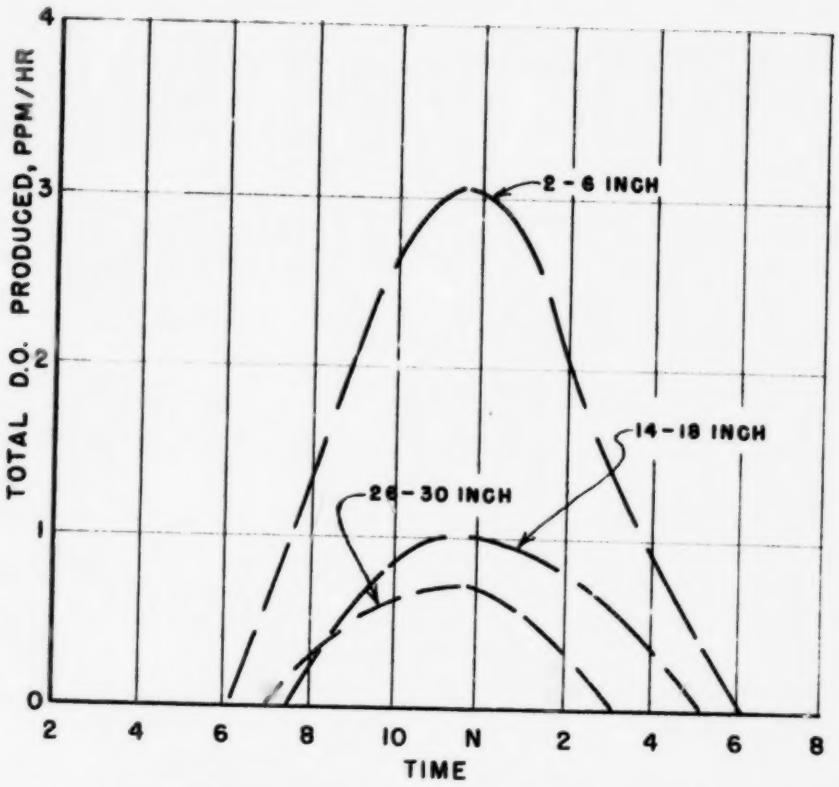

Figure 15. Diurnal Oxygen Production at Indicated Depths - Dec. 23

Plankton Enumeration

Because algal specie and number are important to oxygen production in an oxidation lagoon, an effort was made to identify the most prevalent specie and to count and measure the volume of plankton in the two cells. Attention is called to the appendix for the results of these determinations.

Samples were collected from 6 inches below the surface at the point of discharge of the two cells and a specie determination and count of the phytoplankton was made under a 100-power microscope with the aid of a nannoplankton counting slide. Portions of these same samples were then placed in a centrifuge and turned at 3000 rpm for 15 minutes. The residue was then measured and recorded as solid volume ml/100 ml. Typical species are recorded photographically as an interest item. Figure 16 illustrates a typical population.

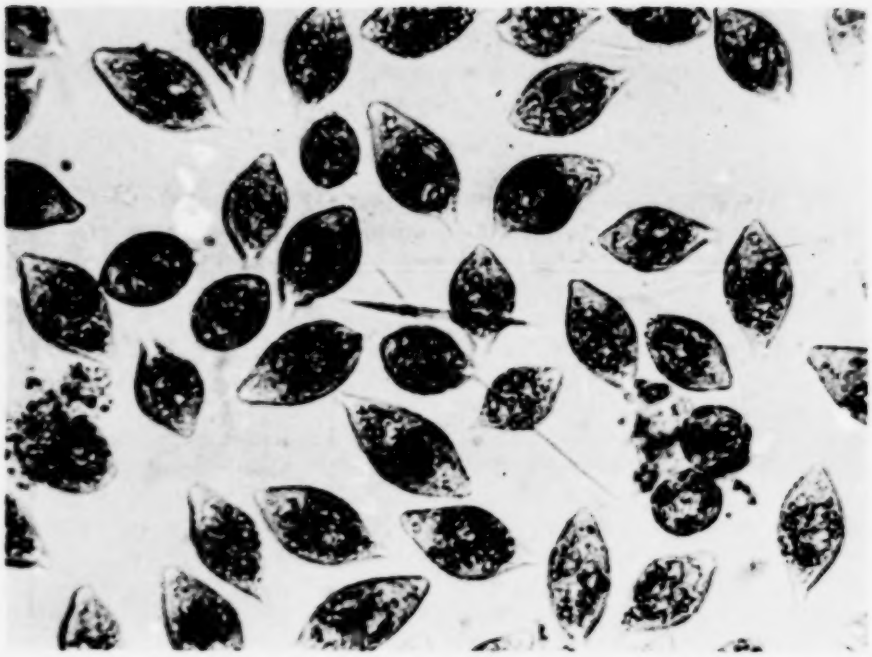

Figure 16. Typical Plankton Population

Water Balance

A significant portion of the waste water entering a lagoon is discharged to the atmosphere in the form of water vapor. An e· amination of the net precipitation minus evaporation for the summer months as determined from pan studies yields the data in Table 8. Evaporation data have been converted to equivalent people per surface acre on the basis of 100 gallons per capita per day, or 3000 gallons per capita per month.

Table 8. Water Balance Data

Month	Precipitation-evaporation inches	gallons	Equivalent persons/acre
June	- 5.59	151,729	50.3
July	- 8.94	242,738	80.8
August	- 5.00	135,760	48.5
September	- 4.29	121,912	40.4
4	24.02	652,139	220.0

Figure 17 gives evaporation data from the lagoon and the 25-year average for Corvallis. The curve of precipitation minus evaporation illustrates most nearly the water balance.

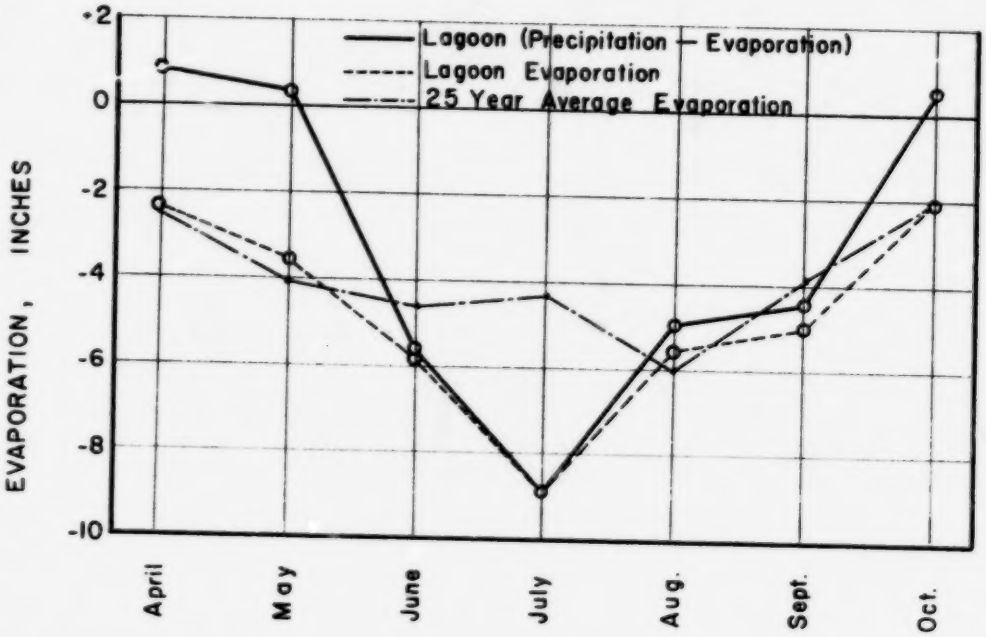

Figure 17. Water Balance

The volume of waste removed by the evaporation mechanism suggests development of data to rely on evaporation plus storage during critical summer months in lieu of discharge effluent. This may be of particular advantage when disinfection is required. On the basis of 3000 gallons/person per month, a contribution of 0.00797 acre feet per month is made by each person. This corresponds to a figure of 125.5 person months per acre foot.

Since inflow - discharge = change in storage, it follows that a lagoon designed with variable depth might store 2 to 3 feet of water during critical summer months. A schedule of storage plus evaporation might be arranged as shown in Table 9 to prevent discharge during low stream flow summer periods.

Table 9. Suggested Operating Schedule

Month	Reliable evaporation in.	Evaporation equivalent population	Storage ft	Storage equiv pop.	Total pop./acre
June	5.59	50	0.60	75	125
July	8.94	80	0.36	45	125
August	5.00	49	0.60	76	125
September	4.49	40	0.68	85	125
		Total storage	2.24		

A multiple level outlet, such that the lagoon could be operated at 2.0-foot depth in late spring and a high water outlet at 4.25 feet, would accomplish this storage benefit of serving a population of 125 persons per surface acre at 100 gallons/capita/day without discharging to the stream.

FUTURE RESEARCH PLANS

In order to obtain maximum objectivity, general research goals have been established for this project. Since the problem of using oxidation lagoons in maritime areas is immediately pressing, it is not reasonable to wait resolution of all basic questions before adopting application criteria. Therefore the basic philosophy during this study has been to proceed on a twofold approach of placing major emphasis on application problems while investigating the more basic problems as a long-term goal.

Many of the research goals of the investigators are not funded under the present grant. They are considered necessary, however, and have been included here for purposes of enumeration. They are as follows:

1. Determination of loading criteria.

Determining the upper dependable limit of loading that will permit aerobic oxidation will remain a primary objective of this project. This value will be variable, depending upon climatological conditions, waste water quality, solar radiation, volumetric loading, and other parameters. Studies to determine these relationships will be continued on a routine basis.

2. Bacteriological quality of lagoon effluent.

The bacteriological quality of a lagoon effluent will vary with time, hydraulic characteristics, and environmental factors. Since this quality reflects a potential health hazard, studies will be made of the bacteriological quality of the experimental lagoon and at other available lagoon installations.

3. Disinfection requirements.

The merits of disinfection are the subject of current study by other investigators. Detailed studies of chlorine disinfection, however, will be continued in this project in order to resolve the engineering problems of application.

4. Reaeration mechanics.

Studies on reaeration mechanisms both from surface and plankton sources will be continued. Mixing as a function of depth, wind velocity, and boundary conditions will be included as possible.

5. Water balance.

Since preventing a discharge during the dry summer months would resolve the problem of disinfection and possible downstream pollution, studies will be continued on evaporation potential and the problems of controlled effluent discharge by storage-evaporation mechanisms.

6. Effluent quality measurement.

Because the major portion of organic material in the lagoon effluent is in the form of living cells, more work on suitable tests of effluent quality must be done. Such a measure is badly needed to predict effluent effects on receiving streams.

7. Soil sealing.

Preventing contamination of ground water and excessive losses of water that may result in stranding of sludge deposits is a problem, particularly with lagoons located in porous soils. Studies of this nature are being planned.

8. Sludge accumulation.

Much of the work of stabilization in an oxidation lagoon proceeds in the lagoon benthos. Studies of sludge accumulation, respiration rate, and oxidation mechanisms will continue as a long-term goal of this project.

9. Industrial waste application.

Adaptation of oxidation lagoons to highly colored industrial wastes will be a major long-term objective of this program. Evaluation of light extinction coefficients, oxygen production, and nutritional requirements will be a part of this study.

10. Removal of algae.

A practical and economic method for the removal of algae from a lagoon effluent would permit more widespread use of lagoons as a waste treatment process and permit their application as a means of removing unwanted nutrient materials. Some work on this problem has been done by other investigators. However, studies to reinforce and expand their findings are considered appropriate to this program.

11. Coastal area application.

Lagoons offer an ideal waste disposal solution to coastal resort areas with a large temporary population. It may be necessary to supplement lagoon water levels with salt water in such areas due to low volumetric loading in times of low tourist use. The effect of varying salinity and shock loading is considered a necessary study area.

APPENDIX

Experimental Data

Data Legend

Color

Code No.	Description
1	Green
2	Greenish gray
3	Gray-green
4	Gray

Odor

No.	Description
Blank	None
1	Very slight
2	Slight
3	Medium
4	Objectionable

Aquatic Forms

A	Posillium	H	Holophra
B	Chlorella	J	Coelastrum
C	Chlorogonium	M	Micratinium
D	Phycotonis	P	Pyrobotrys
E	Euglena	S	Scenedesmus
F	Filamentous green	R	Rotifera
G	Uncoded green		

Units Used in Reporting

Item	Description of units
Flow	Thousands of gallons
Loading BOD & suspended solids	Average of preceding 10-day period
Effluent quality	Measurements of quality at 2:00 PM daily
Physical appearance	Qualitative, based on observer opinion
Precipitation	Inches daily & cumulative total
Precipitation-evaporation	Weekly total (pond reading)
Evaporation	Weekly calculated
Transmittance	Percent at 10 mm light path, 650 micron wave length
Plankton data	
Cell numbers	Per cubic millimeter
Cell volume	Mls per 100 mls of water
Specie	See code

Units Used in Reporting (continued)

Item	Description of units
Bacteriological	Coliform organisms per milliliter (Millipore filter method)
Cl_2 requirement	Mg/L required to obtain 0.5 mg/L residual at end of 30-minute contact

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
April	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1													
2													
3													
4	85.68	140	412	95.6	47.8			20	17	20.4	19.8	7.0	7.3
5	85.68	226	384	95.6	47.8			24	23	21.1	19.1	9.6	9.0
6	85.68	195	268	95.6	47.8			18	11	26.7	32.9	9.7	9.5
7	85.68	165	256	95.6	47.8			27	23	21.8	19.5	8.6	8.6
8	85.68		384	95.6	47.8					10.1	13.6	8.3	7.9
9	85.68	310	616	95.6	47.8			32	26	17.8	18.6		
10	85.68			95.6	47.8								
11	85.68	144	76	95.6	47.8			32	16	14.4	13.4	8.7	9.2
12	85.68	288	436	95.6	47.8			29	19	13	12	8.2	8.2
13	85.68	264	736	95.6	47.8	199.2	99.6	72	22	13.5	12.1	9.3	8.8
14	85.68	140	464	95.6	47.8	201.0	100.7	26	28	12.8	13.5	8.1	7.9
15	85.68	120	184	91.0	45.5	192.8	96.4	22	22	13.6	13.1	8.8	8.7
16	85.68	70	60	85.8	42.9	192.6	96.3	16	19	30.4	38.0	9.4	10.2
17	85.68	270	344	90.4	45.2	194.6	97.3	36	35	13.6	14.0	8.8	8.2
18	85.68	304	840	93.2	46.6	214.2	107.1	70	62	12.7	14.3	8.1	8.0
19	85.68			90.4	45.2	212.4	106.2						
20	85.68	185	300	88.2	44.1	201.4	100.7	47	46	13.4	14.2	9.3	9.0
21	85.68	160		89.0	44.5	194.9	97.2	48	51	15.9	18.1	8.1	9.0
22	85.68	185	362	84.6	42.3	191.0	95.5	20	18	24.2	24.8	9.8	9.9
23	85.68	192	488	81.4	40.7	180.4	90.2	30	28	21.7	25.3	8.2	9.8
24	85.68			85.4	42.7	176.8	88.4						
25	85.68	210	410	88.2	44.1	186.6	93.3	35	36	13.8	12.6	9.3	8.6
26	85.68	158	340	91.8	45.9	190.0	95.0	33	29	29.6	30.3	9.6	9.5
27	85.68	150	242	86.4	43.2	185.6	92.8	31	35	11.6	5.5	8.8	9.0
28	85.68	258	438	84.4	42.2	168.2	84.1	44	26	21.8	21.8	9.4	9.3
29	85.68	284	452	86.2	43.1	163.0	81.5	25	18	32.4	30.6	10.4	10.8
30	85.68	330	578	92.6	46.3	175.2	87.6	43	53	22.7	20.5	9.6	10.0

Date	Temperature			Solar	Physical Appearance				Precip.	Evap.	P-E	Transmittancy	
1960		°F		Data	Odor		Color		P	E		inf.	effluent
Apr	air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.	W	E
1				205.5					0.13				
2				436.1					0.03				
3				482.7					0				
4		68	73	518.9					0				
5		67	67	424.9					0				
6		73	72	427.3					0				
7	75	69	66	450.7					0.11				
8		62	62	326.8					0				
9		64	62	411.8					0.03				
10				512.7					T				
11	46	60	60	409.3					0.31				
12	54	58	57	231.7					0.09				
13		58	58	--					0.23				
14	60	56	56	--					0.36				
15		55	55	--					0.46				
16		64	68	551.1					0.03 (1.78)	1.07	P +0.708		
17		53	54	211.3					T				
18		54	54	154.1					0.12				
19				224.6					0.31				
20		55	55	405.8					0.50				
21		54	55	323.5					0.09				
22		60	61	551.1					0.30				
23		58	58	454.4					T (1.32)	0.72	P +0.60		
24				249.3					T				
25	53	55	54	297.4					0.01				
26	65	67	66	555.2					0.09				
27		58	57	157.8					T				
28	60	65	64	626.7					0.07				
29		70	70	513.7					T				
30		66	66	543.8					0 (0.17)	0.63	E -0.456		

Date	Flow	Waste analysis		10 day ave. load				Effluent Quality					
1960	1000			BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
May	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	85.68			102	50.9	189.8	94.9	32	29	13.1	9.0	9.5	9.1
2	85.68	415	774	112	55.9	207.4	103.9						
3	85.68	201		112	56.1	205,4	102.7	30	24	10.5	16.6	8.8	9.3
4	85.68	282	538	116	57.8	212.2	106.1	26	23	26.1	23.0	9.5	9.9
5	85.68	252	532	117	58.7	217.6	108.8	38	28	22.4	22.8	9.8	9.6
6	85.68	186	202	118	59.3	210.6	105.8	35	29	8.7	2.7	9.4	8.9
7	85.68	210	318	121	60.7	214.8	107.4	35	37	8.0	3.0	8.2	9.0
8	85.68			122	60.9	214.0	107.0						
9	85.68	326	530	124	61.8	217.4	108.7	33	32	24.8	27.5	9.6	9.8
10	85.68	279	326	121	60.7	206.4	103.2	33	36	25.0	19.6	9.6	9.7
11	85.68	244	272	116	57.9	188.8	94.4	34	26	33.4	23.1	10.6	10.4
12	85.68	212	702	107	53.5	185.8	92.9	33	43	9.0	5.9	9.0	8.5
13	85.68	156	528	105	52.5	190.2	95.1	36	31	9.1	8.7	9.1	9.0
14	85.68	192	222	101	50.6	176.4	88.2	31	26	29.8	32.2	9.6	9.7
15	85.68			98	48.8	162.6	81.3						
16	85.68			96	48.0	162.8	81.4						
17	85.68	126	194	92	46.1	157.4	78.7		37	13.3	12.9	8.8	9.0
18	85.68	102	194	85	42.5	147.4	73.7	36	34	14.0	15.7	9.1	9.3
19	85.68	150	568	77	38.6	149.2	74.6	35	36	17.6	15.1	9.2	8.8
20	85.68	132	178	71	35.4	142.8	71.4	32	41	10.8	8.0	8.7	8.4
21	85.68	84	214	64	31.9	140.2	70.1	40	42	15.7	12.0	8.6	8.5
22	85.68	81		60	29.8	124.2	62.1						
23	85.68	77		59	29.5	121.2	60.6						
24	85.68	168	532	58	29.1	134.8	67.4	52	60	10	6	8.5	8.3
25	85.68	108	164	55	27.6	132.6	66.3	66	54	0.2	0.2	7.9	7.9
26	85.68			54	26.9	129.8	64.9						
27	85.68			54	26.9	126.6	63.3						
28	85.68	126	90	55	27.4	122.2	61.1	46	60	12.6	17.7	9.2	9.2
29	85.68	204	418	57	28.6	115.6	57.8	36	38	15.8	31.1	9.8	10.0
30	85.68			59	29.4	120.6	60.3						
31	85.68	142	168	61	30.7	118.6	59.3	40	36	35.6	28.2	10.3	10.6

Date	Temperature			Solar	Physical Appearance				Precip.	Evap.	P-E	Transmittancy	
1960		°F		Data	Odor		Color		P	E		infl.	effluent
May	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.	W	E
1				418.5					0.01				
2	57	64	61	554.5					T				
3	51	60	60	198.2					0.01				
4	55	66	66	338.8					0.32				
5	69	69	72	602.1					0.03				
6		62	60	125.4					T				
7	60	60	60	413.9					0.35 (0.72)	1.02	E -0.30		
8				697.5					T				
9	75	75	72	590.1					0				
10	65	71	70	432.2					0				
11	65	72	79	459.4					0.02				
12	57	64	63	338.5					0.16				
13	61	62	62	416.6					0.64 (0.82)	0.92	E -0.096		
14	61	67	68	403.1					0.03				
15				416.5					T				
16				461.7					0.14				
17	55	60	59	413.6					0.21				
18	60	61	61	547.8					0.29				
19	61	61	61	204.3					0.01				
20	51	60	59	302.9					0.32				
21	55	59	60	61.4					0.13 (1.13)	0.90	P +0.228		
22				460.7					0.17				
23				484.4					0.14				
24	59	61	61	422.1					0.19				
25	55	60	59	195.2					0.22				
26				406.0					0.52				
27				594.5					0.01				
28	56	58	58	643.1					0 (1.25)	0.75	P +0.50		
29	77	75	78	740.6					0				
30				598.2					0				
31	73	78	75	644.5					T				

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2pm	
June	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	85.68	240		66	33.4	120.6	60.3	18	17	33.4	23.1	11.0	10.4
2	85.68	246	596	71	35.6	126.6	63.3	13	24	39.1	19.3	10.6	10.0
3	85.68	252	436	75	37.4	122.4	61.2	17	19	35.3	18.4	10.6	9.8
4	85.68	246	312	81	40.4	128.8	64.4	38	31	27.0	33.6	10.2	10.4
5	85.68			87	43.8	138.0	69.0						
6	85.68			95	47.6	150.0	75.0						
7	85.68	321		104	51.9	165.0	82.5	51	51	12.3	17.5	9.0	8.9
8	85.68	262	472	106	53.2	167.4	83.7	28	63	17.7	27.4	9.2	9.6
9	85.68	364	728	115	57.4	186	93.2	44	32	33.7	36.7	10.4	10.8
10	85.68	360	762	124	62.1	212.4	106.2	60	37	10.4	7.6	9.2	8.9
11	85.68			128	64.1	224.8	112.4	53	48	24.1	25.7	10.0	9.6
12	85.68			131	65.4	223.6	111.8						
13	85.68	276	474	132	65.9	235.2	112.6	52	60	30.3	27.7	10.2	10.7
14	85.68	360	734	137	68.4	243.6	121.8	42	35	0.2	5.0	8.6	10.6
15	85.68	342	546	140	69.9	262.0	131.0	34	46	1.3	2.5	8.4	8.5
16	85.68	258	456	140	70.0	264.6	132.3	32	34	11.4	8.7	8.7	8.5
17	85.68	390	644	143	71.5	273.6	136.8	43	44	27	34	9.7	9.5
18	85.68	273	460	143	71.7	273.0	136.5	38	32	12.9	11.0	8.6	8.5
19	85.68			138	69.1	261.0	130.7						
20	85.68	217		132	66.0	248.6	124.3	23	23	33.3	39.6	9.8	10.0
21	85.68	284	474	130	65	240.2	120.1	31	28	22.4	22.3	9.4	9.3
22	85.68	160	302	134	61.9	228.6	114.3	26	20	23.9	32.8	9.9	9.9
23	85.68		434	129	59.7	226.8	113.4			25.6	23.5	10.0	9.9
24	85.68	189	334	112	56	209.4	104.7	48	29	22.1	20.7	10.5	10.2
25	85.68		242	106	53.3	186.2	93.1			24.4	25.5	10.2	10.2
26	85.68			104	51.9	183.4	91.7						
27	85.68			98	49.1	178.8	89.4	39	51	27.1	23.4	10.7	10.5
28	85.68	292	432	99	49.5	177.6	88.8	59	42	17.5	21.0	9.5	9.8
29	85.68	217		97	48.4	174.4	87.2	32	48	12.6	21.5	9.5	9.8
30	85.68	175	346	95	47.5	169.0	84.5	67	29	1.6	9.2	8.0	10.0

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
June	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1	79	86	83	747.9					0					
2	82	84	83	759.1					0					
3	82	83	83	754.6					0					
4	77	82	81	771.0					0 (0)	1.35	E -1.35			
5				728.2					0					
6				749.6					0					
7	66	73	71	786.4			2	1	0					
8	72	76	76	781.1			2	1	0					
9	77	81	81	754.3			2	1	0					
10	72	74	74	798.5			1	1	0					
11	76	78	78	784.4			1	1	0 (0)	1.77	E -1.77			
12				755.3					0					
13	82	84	84	678.8			1	1	0					
14	69	70	71	183.7			1	1	0					
15	73	69	69	428.3			1	1	0.22					
16	74	70	71	606.9			1	1	0					
17	64	73	73	--			1	1	0					
18		71	68	674.6			1	1	0 (0.22)	1.28	E -1.06			
19				513.4					0					
20	70	73	75	548.1			1	1	T					
21		71	71	785.5			1	1	0					
22	73	78	78	768.5			1	1	(0) 0	0.64	E -0.64			
23	82	84	85	759.1			1	1	0					
24	72	77	76	695.0			1	1	0					
25	68	75	75	803.6			1	1	0 (0)	0.77	E -0.77			
26				746.1					0					
27	75	83	82	777.8			1	1	0					
28	79	82	81	752.5			1	1	0				88	87
29	73	82	82	536.8			2	1	0				86	91
30	72	73	72	438.9			2	1	0			80 86	87 73	90 86

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre/day		BOD		DO at 2 pm		pH at 2 pm	
July	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	85.68	272	222	94	47.2	164	82.2	43	46	7.6	23.8	8.4	9.8
2	85.68	280	346	100	49.8	168	84.2	36	37	11.5	19.0	8.7	10.1
3	85.68			106	52.8	172	86.0						
4	82.10	343	638	112	56.2	185	92.6	29	42	15.9	22.7	8.6	10.2
5	82.10	312	784	116	58.3	209	104	32	43	17.6	23.2	9.3	10.5
6	84.00		324	119	59.6	205	103			25.7	19.6	9.6	10.1
7	84.00	287	440	120	60	201	100.7	32	62	21.6	22.0		
8	84.00	280	444	120	59.9	202	101	46	46	13.3	21.5	9.2	10.1
9	84.00	350	690	126	63.3	215	107.5	95	79	11.1	2.0	9.2	9.4
10	84.00			134	67.1	228	114.2						
11	84.00	350	610	138	68.8	239	119.5	41		30.9	13.0	9.2	9.0
12	84.00	290	348	138	69	245	122.3	66	68	13.9	20.5	8.8	9.1
13	82.10	308	764	138	68.8	255	127.7	84	38	4.8	0	9.1	8.9
14	82.10	260	460	134	66.8	247	123.6	52	41	14.6	11.1	9.2	9.4
15	82.10	232	578	130	64.9	240	118.9	81	23	10.9	7.2	8.3	8.4
16	82.10	245	348	127	64	238	119	20	6	19.2	6.2	8.7	7.7
17	82.10			125	62.5	236	117.6						
18	82.10	231	392	123	61.3	232	116	34	20	22.7	20.0	9.0	8.2
19	82.10	216	498	117	58.3	224	111.8	22	47	25.0	17.0	9.1	8.2
20	82.10	270	456	113	56.5	215	107.3	23	16	20.4	17.5	9.1	9.1
21	80.00	231	402	107	53.7	205	102	25	14	18.4	14.7	9.1	9.3
22	80.00			106	52.8	203	101	30	41				
23	80.00	287	620	104	52.2	196	98	35	16	16.2	15.5	9.1	9.0
24	80.00			102	51.2	197	98.5						
25	80.00	140	360	98	49.2	188	73.7	51	53	18.3	23.2	9.4	9.6
26	78.10	252	456	98	49.2	191	95.8	47		11.3	10.5	8.4	9.2
27	78.10	226	338	99	49.4	189	94.5	34	42	28.5	38.0	10.4	10.7
28	78.10	259	186	99	49.7	180	90	38	42	22.8	26.1	10.1	10.6
29	78.10	190		98	48.9	171	85.7	37	53	16.6	22.1	9.7	10.6
30	78.10	196	436	94	47.1	169	84.8	50	31	2.7	2.9	8.6	8.9
31	78.10			94	47.0								

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
July	Air	W	E	$\frac{gmcal}{cm^2}$	W	E	W	E	in.	in.	in.		W	E
1	68	74	74	627.4			1	1	0					
2	73	75	75	779.2			1	1	0 (0)	1.78	E -1.78			
3				770.4					0					
4	80	78	78	779.5			1	1	0					
5	89	82	81	744.7			1	1	0					
6	97	92	94	760.5			2	1	0					
7	85	83	84	717.6			2	1	0					
8	77	78	78	788.2			2	1	0					
9	76	77	74	--			3	1	0 (0)	-1.96	E -1.96			
10							3	1	0					
11	78	82	77	--			3	1	0					
12	82	75	81	693.9			3	1	0			90	86	88
13				550.0			4	1	0					
14	78	80	79	743.7			4	1	0					
15	88			744.6			3	3	0					
16	93	85	85	732.4			2	*	0 (0)	1.37	E -1.37			
17				740.0					0					
18	87	87	88	696.6			1	1	0					
19	83	84	84	738.3			2	4	0					
20	79	79	78	725.6			2	3	0					
21	81	79	78	734.4			2	2	0					
22				738.3					0					
23	75	75	75	743.2			1	1	0 (0)	2.06	E -2.06			
24				688.3					0					
25	85	80	78	446.2			1	1	0					
26	93	83	73	567.9			3	1	T					
27	92	88	88	652.8			2	1	0					
28	93	87	87	704.7			2	1	0					
29	87	84	84	573.1					0					
30	74	74	74	609.1			2	1	0 (0)		E			
									0	1.77	-1.77			

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
Aug	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	78.10	273		94	47.1	173.2	86.6	44	26	5.8	6.9	8.4	8.3
2	71.40	256	586	92	45.8	175.4	87.7	48	50	12.2	10.1	8.9	9.2
3	78.10	231	564	92	46.0	172.4	86.2	38	52	15.1	12.5	9.4	9.9
4	80.00			94	47.1	166.2	83.1	55	65			9.1	9.5
5	80.00	154	134	90	45.1	156.8	78.4	52	68	24.3	20.3		
6	80.00	231	212	89	44.5	146.8	73.4	35	54	16.9	13.2	9.5	9.6
7	80.00			86	42.8	145.8	74.9						
8	80.00	190	554	82	41.3	165.8	82.9	54	46	11.2	27.2	9.5	10.5
9	72.00	248	672	84	41.9	181.8	90.9	50	45	10.0	9.5	9.3	9.6
10	72.00	140	352	80	40.2	179.2	89.6	37	36	11.0	17.5	9.2	9.9
11	72.00	350	974	84	42.2	200.2	100.1	49	40	21.0	19.4	9.7	9.9
12	72.00	273	600	87	43.3	202.2	101.1	49	47	18.6	14.3	9.7	9.9
13	72.00		316	90	45.1	192.8	96.4			14.1	12.1	9.2	9.4
14	72.00			96	48.2	193.0	96.5						
15	84.00	360	718	106	52.8	203.0	101.5	48	39	12.6	10.6	9.2	9.4
16	84.00	262		107	53.6	210.6	105.3	70	60	28.4	32.1	10.0	10.7
17	84.00	420		118	59.2	212.2	106.1	57	42	17.8	16.8	9.5	9.7
18	84.00			131	65.5	207.4	103.7						
19	85.68	370	480	138	68.9	199.0	99.5	70	39	21.3	21.7	9.9	10.2
20	87.50	320	376	146	73.2	201.2	100.6	48	36	17.6	19.5	9.5	10.0
21	87.50			143	71.5	189.4	94.7						
22	87.50	190	940	140	70.0	206.4	103.2	57	39	3.3	8.9	8.1	9.0
23	87.50			137	68.4	225.2	112.6						
24	72.58	290	576	134	66.8	232.6	116.3	32	28	13.8	3.4	8.5	8.3
25	65.65			128	63.9	238.2	119.1						
26	65.65	250	608	125	62.7	242.2	121.1	51	57	15.1	13.9		
27	65.65	480	572	124	61.8	244.0	122.0	132.2	67	14.0	13.8		
28	65.65			123	61.7	246.0	123.0						
29	65.65	520	646	125	62.5	247.8	123.9	61	55	14.1	8.4	7.6	9.4
30	65.65			125	62.4	248	124						
31	65.65	330	356	124	62.2	132	116	106	60	0	22.0	7.0	10.4

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
Aug	Air	W	E		W	E	W	E	in.	in.	in.		W	E
1	73	73	73	475.1					0					
2	73	73	73	490.9			1	1	0					
3	74	77	76	657.7			1	1	0			87	92	91
4	74	75	75	694.7			1	1	0					
5	76	80	79	680.4			1	1	0			90	88	94
6	80	78	78	698.2			1	1	0 (0)	1.55	E -1.55			
7				677.6					0					
8	98	82	91	677.4			1	1	0			91	92	95
9	80	78	77	640.1			1	1	0					
10	80	78	80	548.1			1	1	0			92	87	92
11	68	73	73	355.3			1	1	0					
12	75	75	74	537.1			1	1	0			92	85	91
13	70	73	73	669.8			1	1	0 (0)	1.63	E -1.63			
14				669.2					0					
15	71	71	71	403.8			1	1	0.02			93	89	93
16	80	78	80	531.1			1	1	0					
17	82	77	76	655.3			1	1	0			95	93	95
18				631.5					0					
19	76	78	77	615.3			1	1	0			92	88	93
20	70	74	74	650.6			1	1	0 (0.02)	1.68	E -1.66			
21				422.1					0.07					
22	59	65	65	265.3			1	1	0.04			95	87	92
23				168.7					0.19					
24	62	64	64	310.9			1	1	0.22			82	82	82
25				273.5					0.03					
26				420.7			1	1	0.01					
27				613.7			1	1	0.05 (0.61)	0.77	-0.16			
28				588.0					0					
29				525.4			1	1	0					
30				572.7					0					
31				142.1	2		1	1	0.01			85		

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2 pm	
Sept	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	66.7			126	63.2	202	100.9						
2	66.7	300	320	127	63.4	181	90.3	110	54	0	10.3	6.6	9.2
3	66.7			124	62.2	171	85.5						
4	66.7			122	60.8	162	81.6						
5	66.7	160	416	119	59.3	157	78.5	119	50	0	18	6.7	9.0
6	66.7			110	54.7	150	74.8						
7	22.2	250	292		50.6		69.4	132	63	0	12.5	6.9	8.7
8	22.2				48.5		62.5			0	9.0	6.8	8.2
9	22.2	520	194		50.3		56.8	126	82	0	13.2		
10	22.2				52.3		53.5			0	38.2	7.0	10.2
11	22.2				53.2		50.8						
12	22.8				53.9		48.8	87	78	0	12.7	7.2	9.1
13	22.8				55.0		46.2						
14	22.8	280			56.5		43.1	66	75	0	8.1		
15	22.8				61.7		39.5						
16	22.8	610			69.0		37.1	84	80	3.0	25.0	7.3	9.0
17	22.8				75.2		35.8						
18	22.8				78.2		35.5						
19	22.8	550			79.5		36.0	60	93	4.2	0	7.3	7.2
20	22.8				81.9		36.5						
21	23.2	575			86.0		37.1	63	85	6.4	9.7	7.4	7.8
22	23.2				89.8		37.7						
23	23.2	480			93.3		38.3		88	6.0	0.6	7.3	7.1
24	23.2				96.4		38.9						
25	23.2				95.8		39.6						
26	23.2	350	244		91.6		40.5	38	74	14.4	14.3	8.2	8.5
27	23.2				86.7		42.0						
28	23.7	400	350		81.2		44.5	36	77	25.6	18.3	9.4	9.4
29	23.7				78.8		48.7						
30	23.7	555	544		78.8		54.5	33	88	7.6	0.8	8.5	7.4

Period of recovery

Period of recovery

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Sept	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1				291.2					0.02					
2	69	69	68	529.2	3		2	1	0.06 (0.09)	0.97	E -0.88	94	76	88
3				408.1					0					
4				285.9					0.35					
5	66	72	72	398.6	4		2	1	T			80	77	88
6				580.8					0					
7	72	70	68	568.8	4		2	1	0			81	74	89
8				564.7					0			80	74	90
9	90	78	75	425.7	2		1	1	0 (0.35)	1.16	E -0.81	85	74	91
10	90	80	78	467.1	2		2	1	0					
11				455.0					T					
12	68	72	73	366.0	2		2	1	0			74	77	89
13				448.4					0					
14	73	73	72	405.7	2		3	1	0			85	79	85
15				406.0					0					
16	66	72	72	363.6	1		2	1	0					
17				263.4					0					
18				445.4					0					
19	62	66	65	228.9			2	1	0 (0)	1.46	E -1.46			
20				490.2			2	1	0.09					
21	69	66	66	505.6			2	1	0				90	86
22				383.8					0					
23	66	64	64	204.0			2	1	0					
24				308.3			1	1	0					
25				375.7					0					
26	73	72	72	356.4			1	1	0					
27				370.2					0					
28	77	75	75	418.0			1	1	0				91	87
29				448.2					0					
30	88	70	72	422.2			1	1	0 (0.09)	1.43	E -1.34		89	83

Date	Flow	Waste		10 day ave. load					Effluent Quality				
1960	1000	analysis		BOD /acre /day		SS /acre /day			BOD		DO at 2 pm		pH at 2 pm	
Oct	gal	BOD	SS	W	E	W	E		W	E	W	E	W	E
1	23.7				78.2		59.4							
2	23.7				77.9		63.4							
3	24.1	480	230		77.9		66.6		33	60	5.4	0	8.7	7.2
4	24.1				78.7		68.9							
5	24.1				80.3		70.3				14.0	17.2	9.5	9.5
6	24.1				82.6		70.8							
7	24.1	100	216		85.9		69.3		29	67	0.7	0	7.3	7.2
8	24.1				90.3		70.2							
9	24.1				90.0		72.7							
10	24.5	480	730		91.1		76.6		50	55	2.8	5.2	7.7	7.4
11	24.5				91.2		76.7							
12	24.5		238		92.4		73.0				1.3	2.8	7.3	7.2
13	24.5				94.7		73.7							
14	24.5	630			97.8		78.9		27	52	6.2	11.0	8.1	8.7
15	24.5				98.1		82.0							
16	24.5			91	95.6	166	83.0							
17	32.2	450	358	180	90.3	164	82.1		32	102	8.2	15.8	7.8	9.0
18	48.2			173	86.3	156	78.2							
19	49.1	520	282	167	83.7	143	71.3		60	62	0	0	7.3	7.1
20	49.1			162	81	123	61.6							
21	49.1			155	77	114	56.8							
22	49.1			146	73	114	56.9							
23	49.1			136	68	108	53.8							
24	48.2	500	424	124	62.4	95	47.4		39	50	0	1.0	7.1	7.1
25	48.2			118	59	86	43.0							
26	48.2	110	280	116	58	81	40.6		45	53	0	0	7.0	7.1
27	48.2			120	60	81	40.6							
28	48.2	90	196	120	60.2	79	39.7		25	30	0	0	7.1	7.0
29	48.2			118	58.8	80	40.1							
30	48.2			114	57.3	83	41.8							
31	48.2	380	572	111	55.7	89	44.7		55	39	0	0	7.2	7.1

Period of recovery

Period of recovery

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Oct	Air	W	E	$\frac{gm\ cal}{cm^2}$	W	E	W	E	in.	in.	in.		W	E
1				415.0					0					
2				416.9					0					
3				244.9			1	1	0			76	88	82
4				385.5					0					
5	65	65	65	336.1			1	1	0					
6				244.7					0.22					
7	62	64	64	121.8			1	1	0.28					
8				252.8					0.52 (1.02)	0.34	P +0.68		91	85
9				372.7					0.06					
10	63	58	57	397.7			1	1	0				85	84
11				69.2					0					
12	50	56	55	254.7			1	1	0.24				90	83
13				254.7					0.12					
14	64	58	61	322.0			1	1	0.01 (0.43)	0.57	E -0.14		87	86
15				313.0					0					
16				346.9					0					
17	74	66	65	330.9			1	1	0				89	83
18				228.1					0					
19	55	58	58	50.3			Δ	1	0				86	81
20				218.7					0					
21				121.9					0					
22				190.0					0					
23				64.8					T					
24	60	60	58	196.2	3	3	1	1	0.26			66	89	87
25				277.1					0					
26	60	58	58	203.8	3	3	1	1	0.11			82	87	83
27				56.2					0.28					
28	59	56	58	131.7	4	2	1	1	0.37 (1.02)	1.12	E -0.10	83	85	81
29				274.9					0.01					
30				105.1					0					
31	57	57	55	56.2	2	1	1	1	0.04				86	88

Date	Flow	Waste		10 day ave. load					Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day			BOD		DO at 2 pm	pH at 2 pm
Nov	gal	BOD	SS	W	E	W	E		W	E	W	E	W	E
1	48.2			106	53.1	93.0	46.5							
2	48.2	196	1218	98	49.3	94.2	47.1		45	36	0	0.3	7.1	7.2
3	16.1				47.7	93.0	46.5							
4	16.4	546	308		48.6	92.0	46.0		43	25	0.5	6.8	7.1	7.4
5	16.4				48.9	92.6	46.3							
6	16.4				48.6	94.0	47.0							
7	16.4	357			47.7	96.2	48.1		36	32	0.8	7.7	7.1	7.8
8	16.4				48.0	94.8	47.4							
9	16.4	483	252		49.4	90.0	45.0		34	25	2.2	1.8	7.1	
10	16.4				49.4	81.0	40.5							
11	16.4	294	174		49.5	72.8	36.4		28	17	9.6	11.5	7.2	7.9
12	16.4				50.2	66.2	33.1							
13	16.4				48.3	61.4	30.7							
14	16.4	182			43.8	58.2	29.1		19	20	7.2	6.7	7.1	7.4
15	16.4				40.5	55.2	27.6							
16	16.1	238			38.3	52.6	26.3		17	18	12.2	11.3	7.9	7.8
17	16.1				36.8	50.4	25.2							
18	16.1				34.2	48.6	24.3				9.2	3.3		
19	16.1				30.7	47.2	23.6							
20	16.1				28.7	47.0	23.5							
21	16.1	70			27.6	47.6	23.8		7	17	10.3	8.4	7.3	7.5
22	16.1				27.0	48.4	24.2							
23	16.1				26.7	49.0	24.5							
24	16.1				26.7	49.6	24.8							
25	16.1	35			26.2	50.4	25.2		0	12	13.5	9.2		
26	72.4			51	25.4	51.0	25.5							
27	72.4			50	24.6	51.8	25.9							
28	72.4	105	148	48	23.8	52.6	26.3		14	12	15.3	13.4	8.6	8.5
29	72.4			49	24.6	55.2	27.6							
30	73.6	280	252	54	27.1	59.6	29.8		19	11	13.9	12.7		

Period of recovery

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
Nov	Air	W	E	gm cal / cm^2	W	E	W	E	in.	in.	in.		W	E
1				244.8					0.12					
2	50	54	54	86.9	4		1	1	0.06				86	87
3				277.4					0.36					
4	57	52	51	263.5	2		1	1	0		E		82	88
5				267.9					0 (0.59)	0.76	-0.17			
6				210.3					0					
7	56	50	50	109.4			1	1	0				85	89
8				216.6					0					
9	47	48	48	161.6			1	1	0				83	82
10				53.3					0.04		P			
11	53	50	51	150.2			1	1	1.21 (1.25)	0.42	+0.83		88	91
12				93.1					0.03					
13				214.2					0.30					
14	47	49	48	167.6			1	1	0.57			85	91	88
15				36.4					0.78					
16	54	52	53	150.5			1	1	0.32			81	90	86
17				37.5					0.09					
18	51	51	50	178.7			1	1	0.89 (2.98)	0.22	P +2.76		91	89
19				52.2					0.11					
20				45.8					0.55					
21	47	48	48	121.5			1	1	0.54			90	93	91
22				63.5					0.09					
23				22.6					0.54					
24				10.5			1	1	2.07 (3.90)		P +4.85			
25	46	46	46	113.1					1.79					
26				97.1					0.03					
27				154.6					0					
28	41	45	46	114.8			1	1	0			79	94	92
29				103.1					0					
30	45	43	43	42.4			1	1	0.01				93	95

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2pm	
Dec	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	73.6			58	29.2	64	32						
2	73.6	224	236	62	30.9	68	34	19	14	5.8	6.5	7.1	7.4
3	73.6			65	32.7	70	35						
4	73.6			69	34.6	72	36						
5	73.6	228	174	73	36.6	74	37	17	13	2.0	5.6	7.1	7.4
6	73.6			78	39.3	78	39						
7	73.6	308	302	86	42.9	82	41	23	16	0.9	5.4		
8	73.6			94	47.1	88	44						
9	73.6	350	286	100	50.1	92	46	50	20	0.3	5.6	7.1	7.1
10	73.6			102	50.9	92	46						
11	73.6			102	51.1	90	45						
12	73.6	196	174	102	50.6	88	44	40	21	0.2	0.7	6.9	7.1
13	73.6			100	49.9	90	45						
14	73.6			98	48.9	94	47						
15	73.6			96	47.7	100	50						
16	72.4	146	442	92	45.5	108	54	48	36	0.1	0.3	6.7	7.0
17	72.4			86	42.5	110	55						
18	72.4			78	39.0	110	55						
19	72.4	56		70	35.0	108	54	32	35	0.4	0.85	7.0	7.0
20	71.0			64	31.6	104	52						
21	69.6	140	79	58	29.3	100	50	34	20	0.40	1.10	6.8	7.2
22	69.6			56	28.2	96	48						
23	69.6			54	27.3	88	44						
24	69.6	63	58	54	26.7	80	40	33	30	0.1	0.2	6.8	7.0
25	69.6			52	26.3	68	34						
26	69.6			52	26.1	54	27			0.3	0.9	6.5	6.9
27	69.6			52	25.9	42	21						
28	69.6	140	74	52	25.7	34	17	29	21	0	0.3	6.7	6.9
29	69.6			54	26.9	30	15						
30	68.3	238	212	56	28.4	32	16	47	21	0	0.4	6.7	6.9
31	68.3			60	30.1	36	18						

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Dec	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1									0.08					
2	54	46	46				1	1	0.02 (1.93)	1.98	E -0.05	77	95	92
3				88.1					0.11					
4				165.2					0.06					
5	35	43	43	52.1			1	1	0.04			80	97	92
6				168.9					0					
7	44	42	42	185.7			1	1	0					
8				177.7					0					
9	41	40	40	137.7			1	1	0				91	90
10				38.2					0					
11				21.4					0.04					
12	64	47	45	157.0					0.17					
13				88.9					0.02					
14				82.6					0					
15				108.1					0					
16	41	44	43	39.5	2		4	1	0.10				88	88
17				29.3					0.80					
18				23.5					0.85					
19	54	47	46	76.6			4	1	0.58 (2.77)		P +2.86		88	92
20				56.3					0					
21	36	44	43	44.6	1		4	4	0				99	99
22				53.9					0					
23				44.1					0					
24	36	42	42	44.2	2	2	4	4	0 (0)	0.56	E -0.56		94	96
25				30.8					0.07					
26	50	45	44	127.3	3	3	4	4	0.27				95	97
27				105.6					0					
28	36	41	41	164.7	2	3	4	4	0				95	97.5
29				172.3	1	[illegible]			0					
30	30	39	39	51.1	1	1	4	4	0				95.5	97
									0.11 (0.45)	0.10	P +0.35	(79)	(92)	(91)

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
Jan	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	68.3			64	32.1	42	21						
2	66.7			69	34.4	46	23						
3	66.7	300		73	36.8	52	26	48	22	0.0	0.5	6.2	6.6
4	66.7			77	38.4	58	29						
5	66.7			75	37.4	62	31	63	23	0.2	1.2		
6	65.4			79	39.7	68	34						
7	65.4	98	146	78	38.7	74	34	53	26	0.02	0.06	6.70	6.85
8	65.4			74	37.2	70	35						
9	65.4			69	34.7	70	35						
10	65.4	63	188	64	31.8	70	35	6	6	2.6	7.0	7.1	7.2
11	64.0			59	29.5	70	35						
12	62.5	189	248	56	27.8	72	36	12	6	2.3	2.6	7.1	7.2
13	62.5			49	24.7	74	37						
14	64.0	49		42	21.2	76	38	35	16	0.8	4.3	6.70	6.95
15	85.4			39	19.7	78	39						
16	85.4			40	20.1	82	41						
17	85.4	203	226	45	22.3	84	42	31	16	4.8	12.0	7.0	7.4
18	85.4			49	24.3	86	43						
19	85.4	147	102	52	25.9	84	42	19	5	7.7	14.8		
20	83.4			53	26.6	84	42						
21	81.7	49	278	51	25.4	88	44	30	21	2.8	14.7	7.0	6.2
22	81.7			48	24.2	90	45						
23	81.7			50	24.8	90	45						
24	81.7	152	162	54	27.2	88	44	27	16	9.0	15.8	7.4	8.0
25	122.5			61	30.6	98	49						
26	122.5	245	502	70	35.1	120	60	17	12	9.7	18.0	7.3	8.1
27	118.8			76	38.0	138	69						
28	118.8	224	404	82	41.2	154	77	18	13	9.0	17.2	7.2	8.4
29	118.8			88	43.8	168	84						
30	122.5			92	46.2	172	86						
31	122.5	100	96	97	48.4	166	83	17	11	7.3	14.5	7.1	8.0

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1961		°F		Data	Odor		Color		P	E		infl.	effluent
Jan	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.	W	E
1				64.7					T				
2				26.2					0.11				
3	36	40	39	57.9			4	4	0				
4				108.6					0			98	96.5
5				58.0	1		4	4	0.61				
6				43.5					0.84				
7	48	46	45	56.6			4	3	0.21 (1.17)	2.91	-1.14	88.5	94
8				32.2					0.66				
9				118.0					0.17				
10	54	49	49	96.9			3	2	0.01			94	94
11				38.1					0				
12	45	45	45	81.9			3	2	0.14		99	93	96
13				115.6					0.22				
14	46	48	46	76.9			2	2	0.26 (1.46)	0.18	+1.28	101 89	94
15				40.6					0.04				
16				80.1					0.08				
17	60	51	50	130.5			2	2	0.02				
18				199.8					0				
19	54	48	47	170.4			1	1	0		99	97	96
20				207.1					0				
21	43	45	45	205.5			1	1	0 (0.14)	0.14	0.00	99.5 96	97
22				215.1					0				
23				93.7					0.02				
24	43	46	46	162.7			2	1	0.01		98	93	95
25				--					0.01				
26	53	47	47	194.5			1	1	0		99	96	97
27				157.5					0				
28	55	50	47	202.3			1	1	0 (0.04)	0.39	-0.35	97	95
29				87.0					0.31				
30				57.4					0.27				
31	59	53	51	202.1			1	1	0.81				

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2pm	
Feb	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	125.2			99	49.5								
2	125.2	75		99	49.5			26	15	11.1	12.3	7.2	8.1
3	125.2			95	47.7								
4	125.2	28		86	43.2			21	12	12.5	10.0	7.35	7.30
5	127.8			74	37.0								
6	125.0			64	31.8								
7	112.2	95		55	27.6								
8	112.2			48	23.9								
9	109.0	48		42	20.8								
10	141.0			37	18.3								
11	0	22		31	15.5			12	22	7.0	7.5	7.3	7.3
12	0			26	13.1								
13	0			23	11.5								
14	0			21	10.6								
15	112.1			19	9.6								
16	138.0	30		17	8.6								
17	138.0			15	7.3								
18	145.2	45		14	7.0			15	6	15.1	8.6	6.0	7.0
19	145.2			15	7.6								
20	145.2			18	9.2								
21	149.7			23	11.7								
22	149.7			29	14.5								
23	149.7			35	17.6								
24	154.0			42	20.9								
25	308.0	44	202	48	23.9			12	10	15.4	9.7	8.6	7.9
26	327.0												
27	327.0												
28	351.0	131											
29													
30													
31													

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1961		°F		Data	Odor		Color		P	E		infl.	effluent
Feb.	Air	W	E	gm cal / cm^2	W	E	W	E	in.	in.	in.		W E
1				49.4					T				
2	52	52	51	79.2			1	1	0.32			99	95 97
3				88.7					0.11				
4	53	53	52	86.9			1	1	0.05		+1.88		98 98.5
5				98.5					0.08				
6				177.4					0.64				
7				113.6					0				
8				91.9					0.11				
9				34.6					0.45				
10				29.9					2.76				
11	48	50	50	122.5			3	3	1.11 (5.10)	0.63	+4.47		98 100
12				99.0					0.36				
13				72.4					0.22				
14				129.4					0.24				
15				216.1					0.69				
16				196.8					0.06				
17				177.6					0.16				
18	44	48	47	137.4			1	1	0.05				88.5 83
19				126.9					0.16				
20				120.6					0.04				
21				88.1					0.05				
22				199.6					0.69				
23				190.7					0.04				
24				103.9					0				
25	49	47	47	221.8			1	2	0.85				
26				269.1					0.24				
27				253.0					0.44				
28				178.8					0.04				
29													
30													
31													

Evaporation pan washed out

Date	Plankton Data						Bacteriological			Cl_2 Reqmt		mg/L
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Apr	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13	222	260	0.16	0.12	M	E						
14												
15												
16		425	0.11	0.10	F	DMS						
17												
18												
19												
20			0.08	0.09	EMS	EMS						
21												
22								20		100,000		
23			0.10	0.10	MS	MS				5,300		
24												
25												
26												
27												
28												
29												
30			0.11	0.12	REM	REM						

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
May	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2												
3												
4												
5												
6					R	R						
7						R						
8												
9												
10												
11			0.09	0.08	B	B						
12												
13												
14												
15												
16												
17												
18	77	119	0.14	0.13	M	M						
19												
20												
21	102	212	0.16	0.17	M	AM						
22												
23												
24												
25			0.14	0.12	BE	BE						
26												
27												
28												
29												
30												
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res at 30 min.		
June	W	E	W	E	W	E	W	E	iological	W	E	Raw
1			0.05	0.04	B	B						
2												
3												
4			0.06	0.04	B	BES						
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20	410	445	0.08	0.10	BS	BS	7000	10,000	17,000			
21												
22												
23	400	330	0.12	0.16	BES	BS						
24			0.13	0,14								
25												
26												
27												
28			0.09	0.14			33,000		1,000			
29	186	706	0.03	0.11	BS	BES						

Date	Plankton Data				Bacteriological				Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.	
July	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2												
3												
4												
5												
6	66	510	0.04	0.11	BS	BES						
7												
8	166	497	0.07	0.14	BES	MES						
9	492	532	0.04	0.2	BEJ	BMS						
10												
11												
12	106	93	0.06	0.17	E	BEJ						
13												
14							380	315	4,000			
15	153	40	0.05	0.03	BEJ	MS						
16												
17												
18												
19	100	53	0.06	0.02	BCS	BCS						
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Aug	W	E	W	E	W	E	W	E	iological	W	E	Raw
1	630	700	0.01	0.09	BE	BEC	1650	200		6.0	6.0	6.0
2												
3	450	292	0.13	0.14	BE	BE	1020	420	7,000			
4												
5	517	485	0.14	0.11	BCE	BCE	6000	2040	7,000			
6												
7												
8	1120	678	0.12	0.09	BCE	BES	2900	700	35,000	6.0	9.0	5.0
9												
10	680	660	0.13	0.11	BCE	BCES	2460	2600	70,000			
11												
12	580	500	0.14	0.11	BCE	BCE	2900	2300	180,000			
13												
14												
15	570	530	0.14	0.17	BCE	BES	1180	600	25,000	6.0	6.0	10.0
16												
17	600	470	0.11	0.10	BCE	BES	3600	1500	17,000			
18												
19	1040	470	0.14	0.13	BES	BCER	3400	1600		5.0	8.0	4.0
20												
21												
22			0.25	0.27	BE	BES				7.0	7.5	7.5
23												
24	350	100	0.17	0.15	BE	BES	350	100	28,000			
25												
26	400	630			BC	BES						
27												
28												
29	260	510	0.10	0.09	BESR	BES	3800	7900	160,000	13.5	13.5	
30												
31	320	740	0.17	0.22	BER	BERS	1800	650	70,000	10.5	16.0	13.0

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Sept	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2	880	390	0.15	0.30	BE	BERS						
3												
4												
5	420	1160	0.07	0.23	B	BRS				6.0	12.0	6.0
6												
7	420	1080	0.05	0.50	B	BES						
8	370	940	0.04	0.40	B	BERS						
9												
10												
11												
12	500	1040	0.07	0.35	BR	BERS	650	8000	44,000	6.0	8.4	
13												
14	490	1140	0.09	0.34	BERP	BECS		900	21,000			
15												
16	510	690	0.08	0.40	BEC	BECS	200	1750	36,000			
17												
18												
19	660	960	0.13	0.80	BES	BRS				3.0	9.0	9.0
20												
21	700	1020	0.10	0.70	BES	BES	170	1800	11,000			
22												
23	440	1020	0.17	0.22	BES	BES						
24												
25												
26	740	870	0.17	0.22	BES	BES						
27												
28	490	810	0.14	0.22	BES	BCS						
29												
30	410	940	0.17	0.32	BES	BRS						
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/ mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Oct	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2												
3	230	630	0.26	0.14	BCS	BJS						
4												
5												
6												
7	120	850	0.08	0.22	BRS	BCS						
8												
9												
10	140	530	0.12	0.30	BS	BS						
11												
12			0.12	0.28								
13												
14	230	420	0.10	0.26	BS	BCS						
15												
16												
17	30	400	0.08	0.22	EJS	BRS						
18												
19	40	450	0.06	0.24	BJS	BJRS						
20												
21												
22												
23												
24	80	420	0.06	0.16	BS	BRS						
25												
26	40	340	0.06	0.16	BS	BRS						
27												
28	50	330	0.05	0.15	BS	BRS	1200	130	16,000	3	3	2
29												
30												
31	160	330	0.11	0.13	BG	BRS						

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Nov.	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2	240	450	0.05	0.14	BGS	BGS						
3												
4	230	300	0.04	0.13	BS	BRS						
5												
6												
7	340	360	0.04	0.11	BGS	BRS G						
8												
9	270	240	0.05	0.10	BGS	BRS GT						
10												
11	460	200	0.09	0.12	BGS	BEG S		50	2000			
13												
14	210	290	0.08	0.13	BES	BHS						
15												
16	210	290	0.08	0.07	BES	BES						
17												
18												
19												
20												
21	110	210	0.06	0.07	BES	BRG S						
22												
23												
24												
25	170	290			BRS	BRS						
26												
27												
28	200	300	0.025	0.04	BES	BCS						
29												
30	190	300	0.03	0.04	BES	BES						
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Dec.	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2	150	210	0.03	0.105	BRES TG	BRS						
3												
4												
5	150	170	0.02	0.04	BGS	BES						
6												
7			0.01	0.04								
8												
9	60	120	0.02	0.03	BSG	BSG						
10												
11												
12	70	110	0.01	0.02	BG	CRSG						
13												
14												
15												
16	80		0.02		EG	CGRST						
17												
18												
19	20	100	0.02	0.04	R	EGR ST	240	45	5,000	4	2	2
20												
21			0.02	0.03								
22												
23												
24			0.03	0.03						2.8	2	5
25												
26			0.02	0.03								
27												
28			0.02	0.03								
29												
30			0.03	0.03			1400	60	77,000			
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1961	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Jan	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2												
3			0.03	0.02								
4												
5												
6												
7	80	180	0.03	0.04	RET	STB	2200	240	3000	2	2	3
8												
9												
10	90	150	0.03	0.04	REG	BEC G						
11												
12	80	180	0.02	0.02	ESRG	BEG S						
13												
14	110	170	0.04	0.06	GRES	BER GS	240	320	3000	2	2	3
15												
16												
17			0.03	0.04								
18												
19			0.04	0.06								
20												
21			0.04	0.03								
22												
23												
24			0.04	0.06								
25												
26			0.04	0.08								
27												
28	150	250	0.05	0.06	CES	CES	15	15	2500			
29												
30												
31			0.04	0.06								

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1961	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		Bacter-	0.5 res. at 30 min.		
Feb.	W	E	W	E	W	E	W	E	iological	W	E	Raw
1												
2	110	200	0.08	0.12	FGC	CES						
3												
4			0.05	0.06						2.5	2	7
5												
6												
7												
8												
9												
10												
11			0.04	0.05								
12												
13												
14												
15												
16												
17												
18	80	110	0.02	0.03	CSG ER	ER	10	9	8			
19												
20												
21												
22												
23												
24												
25	80	120	0.03	0.03	CEG S	CEG S	300	10	100	0.5	2	2
26												
27												
28												
29												
30												
31												